The Journal of Bone and Joint Surgery

EDITORIALS AND ANNOTATIONS

"FORTY YEARS ON"

It is a platitude to say that we live in a world of rapid change. Although conditions of life have never been static, the story of evolution suggests that its tides have ebbed and flowed at varying rates and that new streams of progress and regression have been hastened by sudden shifts of environment. And so to-day, in this electronic and nuclear age, people in many spheres are anxious about the future: not so much perhaps of life in general, but of the traditional ways of life and of their interests in particular. This is found in medicine no less than in literature and the arts. In *The Times* there has lately been a discussion upon the future of children's hospitals; and in its *Literary Supplement* a special number devoted to the problems of authorship and publication in the midst of the techniques of mass communication. Assuming that we live on the crest of a fast-flowing stream going in which direction we know not, it is perhaps unprofitable to ask what is the future of orthopaedics. Nevertheless can we learn any lessons from the past, remembering Burke's warning not to plan the future upon it? Doubtless in the matter of techniques he was correct, but it is also right that we should inquire into the motives of our predecessors; for " if from the past comes custom, in the future lies adventure." What then were the ideas which directed the adventure of our orthopaedic fathers forty years ago? We may be sure they were not primarily questions of techniques.

Some such thoughts as these clearly influenced the Executive Committee of the British Orthopaedic Association when it invited Sir Harry Platt to deliver the first " Founders' Lecture " at the Oxford meeting in October this year. This annotation goes to press before we have had the pleasure of hearing Sir Harry, but we know that (as one who was the Association's first secretary) he will deal with the characters and circumstances of those early years with wit and understanding, and not without thought for the ideas that we might bear in mind to-day. Many of the facts of the early years of British Orthopaedics were related by Osmond-Clarke in an admirable article published in 1950. It happens, as we have lately been reminded by Philip Wiles, that in its beginnings the British Orthopaedic Association was closely linked with this Journal, and as the circumstances are perhaps not fully recognised we propose to turn its pages for the years 1918–20. The reader should first be reminded that early in this century attempts to establish a British Orthopaedic Society had proven abortive, possibly on account of geographical and personal rivalries. In 1918 the experiences and team work of war had brought men together in greater amity. Even so, it required the diplomacy of Robert Jones and Robert Osgood to complete the submersion of personal feeling which made possible the combination of men from London and the provinces into the fellowship which the British Orthopaedic Association soon became. That it was founded upon British-American friendship is exemplified by the close relationship which was at once established with *The American Journal of Orthopaedic Surgery*, the official publication of the American Orthopaedic Association. The last number of that Journal so called tells the story and gave an account of the first meeting of the British Orthopaedic Association. In the next number, now simply *The Journal of Orthopaedic Surgery*, the editor stated that it became " not less American, not more British but invited to its columns, as always, the best of both nations." It was the only journal in the English language dealing exclusively with orthopaedic surgery, which meant " not merely the past conception of the term in its literal sense of *straightening out the child*, nor even the later pre-war connotation . . . of its broadest exponents, but we have

added all that the orthopaedic surgeon has been called upon to do by the exigencies of war and reconstruction for the straightening out of the grown man. This as Colonel Osgood points out includes some phases of industrial surgery. We see its culmination in the magnificent work done for our soldiers under the guidance of Robert Jones."

That guidance was based upon the early detection of incipient disability, the preservation and restoration of structure and function in the locomotor system whether the result of congenital or developmental defect, disease or injury, and the establishment of special institutions and after-care services for the proper segregation and continuity of treatment of these disabilities from the earliest phases until rehabilitation was achieved. An essential feature was the development of the team concerned with the programme: the surgeons and medical men, nurses, special school teachers, social workers, after-care sisters and physiotherapists, orthopaedic appliance workshops, with vocational training and occupation as essential elements leading to rehabilitation. This was no field for the narrow individualist technician. Education of everybody from the surgical leader down to the patients, with emphasis upon the team work, were the dominant ideas.

With this in mind we can now realise the historic significance of the second annual meeting of the Association in November 1919. For we read that it was then that G. R. Girdlestone presented the plan in which Sir Robert Jones and he outlined the future organisation of orthopaedics in Great Britain, as a regional service with central orthopaedic hospital units and peripheral out-patient clinics providing consultative services for general practitioners in association with public health authorities and other social services, with hospital schools, occupational and vocational training: in fact the whole organisation which we have now inherited and which the Central Council for the Care of Cripples did so much to foster under their stimulus and that of Dame Agnes Hunt and Mrs U. Townsend; and now continued under its president to-day, Lord Nuffield.

Like the British Orthopaedic Association itself, the Robert Jones-Girdlestone plan of 1919 evolved out of the experiences and material facilities which the 1914–18 war had provided. As from the days of Ambrose Paré the exigencies of war and the surgery of trauma had led to the benefit of the peace-time needs of civilians. Nowadays the incidents of war, though not their intent, are becoming more and more paralleled by the incidents of civil life. The accidents of industry and of high speed travel are bigger problems than those combined of congenital abnormalities, tuberculosis, infectious fevers, venereal diseases and acute haematogenous pyogenic infections. It therefore behoves us to ask ourselves "Are we taking our proper part in medicine as a whole, in the social services of orthopaedics and —a particular concern to-day—in the casualty services of the country?"

In medicine, and this applies to its other branches besides orthopaedics, there should be much closer association of physicians and surgeons throughout their work. In orthopaedics we must bring physicians into the team, and ourselves become more physicians though no less surgeons. Thus our medical colleagues would learn the importance of the orthopaedic disciplines and of making use of them earlier rather than later as so often happens to-day in the newly developed medical specialities. An important field where problems arise is in the children's diseases of the locomotor system. It is easy to be critical of our paediatric colleagues: we must be critical also of ourselves, for we have our own particular glass cubicles from which we should not cast bricks.

The great increase in the number and dispersal of specialists has led to a surprising development of official encroachment upon the special hospitals amounting almost to an "attack." The year which has seen the passing of the fortieth in the history of the British Orthopaedic Association has also seen the fiftieth anniversary of Sir Henry Gauvain's work at Alton, where we understand that the change in character is being hastened by one administrative action after another. What is not sufficiently realised is that such an institution, and others like it at Oswestry, Oxford, Stanmore, Harlow Wood, Pyrford and Exeter, are

more than units where a group of surgeons carry out the work of a particular surgical department. It is forgotten that their nursing and other facilities offer a standard of treatment based upon a volume of experience that cannot be found in the small general hospitals of the provinces in which innumerable young men are isolated with overwhelming out-patient work, divorced from the team who could make work easier by skilled nursing and secretarial help and by the critical discussions which sharpen wits and maintain efficiency. The educational function of orthopaedics is indeed just that: not only to train the ignorant.

The proper use of the existing orthopaedic centres—*special* centres if it is preferred—and new ones too, should be to increase the knowledge of the orthopaedic principles of physiological control and rehabilitation. They could then, for example, take back their proper function in regard to amputations and artificial limbs which, together with surgical appliances, could now so much more easily be arranged; since all are under the same ministerial control as the hospitals themselves. These orthopaedic services, if we were to invite physicians to take a more intimate part in them, should also serve the dire needs of the rheumatic cripple. Lastly, and by no means least, these services, linked as they should be not only with peripheral out-patient clinics but also with peripheral general hospital accident departments, should provide important clearing houses in the casualty services of the country. Accidents nowadays are as much a problem of the country districts as of the cities. The application of orthopaedic methods to the casualty services (whether carried out by orthopaedic surgeons or not) was a major gain from two world wars. In many, but still too few, parts of the British Isles, orthopaedic surgeons have assumed a greater responsibility for this work. We emphasise *too few*. A committee of the British Orthopaedic Association is at present engaged in studying this problem and we do not know their recommendations. Suffice it to say that we cannot be complacent with the present position. There are too many casualty departments with only nominal consultant supervision. The incidence of major and minor accidents in transport and industry as well as in domestic circumstances, demands a far better organisation than generally exists, and it is in orthopaedics where this should particularly be found.

Another point that we feel bound to mention touches every department of training, not only orthopaedic. This is the present tendency for too early specialisation. It is not uncommon among men coming for consultant appointments to find no adequate background in general medicine and surgery; no experience in backgrounds of anatomy, physiology or pathology.

So far nothing has been said about research. This is a province which should not be restricted to university centres and postgraduate institutions. The pages of this journal show the considerable amount that is done elsewhere, often under the most discouraging conditions. This is yet one more reason for strengthening the provincial orthopaedic centres.

The future problem of orthopaedics is to improve its integration with general medicine while maintaining proper segregation and organisation: there is no place for isolation. The principles of orthopaedics should be applied to all potentially crippling lesions of the locomotor system from inception to rehabilitation.

NORMAN CAPENER.

PARALYTIC CLAW HAND

With Special Reference to Paralysis in Leprosy and Treatment by the Sublimis Transfer of Stiles and Bunnell

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It is only occasionally that the human hand is used for scratching. In this action the finger nails are the essential instruments, and the pulps are only in the way. Animals of the cat tribe who depend so much on their claws in battle, and animals who use them for digging, like the mole, depend mainly on their profundus muscles to bring their claws into action. They could probably fight and dig without their intrinsic muscles. The spread and retraction, but not the effectiveness, of their claws would be lost.

In the human hand the function of the nails has been superseded by that of the pulp. This beautiful organ of discrimination and power brings to our knowledge the texture of our environment; it is also the means by which we impose our will on the tools that subdue and transform the world for our pleasure.

When the intrinsic muscles of the human hand are paralysed, the power of the grasp is not much affected. There are four main disabilities: 1) The fingers cannot be opened out fully at the interphalangeal joints; 2) the power of abduction and adduction is lost; 3) in grasping an object, flexion begins at the terminal joints, closing the fingers on themselves rather than on the palm; 4) the effective part of the finger becomes the tip and the nail (claw) rather than the pulp.

The first two disabilities have received most of the attention in the literature. Considered functionally, however, the last two matter most.

ANATOMY

The anatomy of intrinsic muscle action has been fully and beautifully analysed by Bunnell (1948), Kaplan (1953), Littler (1949) and others. We do not need to attempt an analysis here, but the following points need emphasis.

Metacarpo-phalangeal joint—The intrinsic muscles are the only prime flexors of the metacarpo-phalangeal joints. The long flexor muscles do flex these joints, but only secondarily; their first action is on the interphalangeal joints. In intrinsic palsy the metacarpo-phalangeal joints have no prime flexor, but retain a powerful extensor, the extensor digitorum.

Interphalangeal joints—In the normal hand these joints may be extended by the unaided action of the intrinsic muscles acting through the lateral band, which lies just dorsal to the joint fulcrum. They may be extended also by the action of the long extensors, provided the intrinsic muscles stabilise the metacarpo-phalangeal joint.

In the absence of the intrinsic muscles the interphalangeal joints have no prime extensor. The attempt to straighten the whole hand leads only to hyperextension of the metacarpo-phalangeal joints until their anterior capsules limit the backward movement. At this stage the residual power of the long extensors may partly extend the interphalangeal joints against the resistance of the overstretched long flexors. As soon as the metacarpo-phalangeal hyperextension is relaxed in beginning to close the hand, the interphalangeal joints again lose all extensor power. The patient therefore always closes his hand by closing his terminal joints first. This means that unless an object is small enough to be grasped by the curve of

the fingers alone, it cannot be grasped at all. In attempting to grasp a large object the presenting finger tips and nails push the object out of the palm instead of surrounding it by the palmar surface of the fingers and pulps which should reach out to encircle it. This reaching out of the fingers is a purely intrinsic action and is the preliminary to all normal grasp and pinch (Figs. 1 to 3).

CORRECTION OF CLAW HAND

Attempts at correction of the disabilities of claw hand fall into three groups.

1. Attempts based on the fact that limitation of extension of the metacarpo-phalangeal joint allows active extension of the interphalangeal joints by the long extensors. This has been done by means of bone block, capsule plication and tenodesis. These operations may succeed in producing a fully open hand. They can never reproduce the active phase of intrinsic action in grasp and touch, because they do not provide for a prime flexor of the metacarpo-phalangeal joint. The hand may appear normal in full extension but it is still a "claw" hand in that its presenting surface for grasp is nail rather than pulp.

2. Operations based on the use of the flexor sublimis as a lumbrical muscle (Stiles 1922, Bunnell 1942). The present series is an analysis of this method.

3. Operations based on the use of an extensor of the fingers as a lumbrical (Fowler 1949) or the use of an extensor of the wrist (Brand 1954). The place of these operations will also be discussed.

All the patients reported in this paper were operated upon by the sublimis transfer operation suggested originally by Stiles (1922) and later worked out and modified by Bunnell (1942). As the technique of operation used here differs a little from the original, it is worth describing it briefly. *Technique of operation*—The operative field is rendered bloodless by a pneumatic tourniquet, and a mid-lateral or dorsi-lateral incision is made along the radial side of the proximal segment and half the

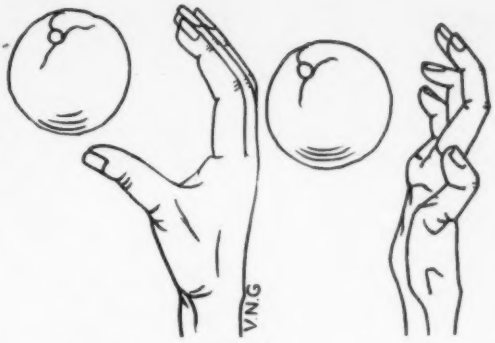

FIG. 1

First stage of grasp. The claw hand on the right has succeeded in extending the interphalangeal joints widely enough to grasp the object. This is done by hyperextending the metacarpo-phalangeal joints.

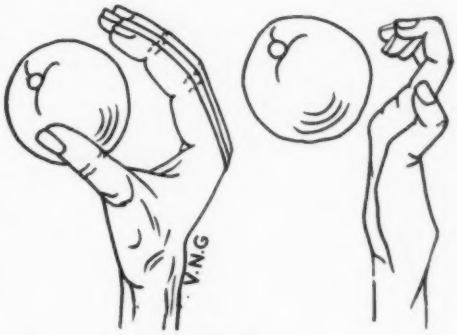

FIG. 2

Second stage of grasp. The attempt to surround the object with the fingers. The claw hand on the right is closing its interphalangeal joints before the metacarpo-phalangeal joints begin to flex. There is no prime flexor for the metacarpo-phalangeal joints.

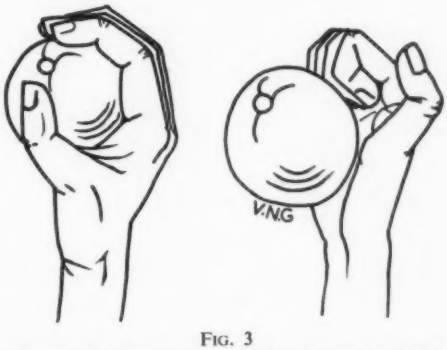

FIG. 3

The completed grasp. The claw hand grasp has failed, not because it lacks powerful flexor muscles, but because the interphalangeal joints flex before the metacarpo-phalangeal joints.

middle segment of each finger. In recent cases the incision has been on the ulnar side of the index finger. The dorsal expansion is identified. The flexor sheath is opened to expose and detach the insertion of the sublimis tendon. The palm is opened by a transverse incision about an inch and a quarter from the web and the sublimis tendons are withdrawn into the palmar wound. Each sublimis tendon is threaded down the lumbrical canal to its own finger. It is then passed through a slit in the lumbrical tendon at the base of the finger and sutured to the lateral border of the dorsal expansion just proximal to the proximal interphalangeal joint. The ring finger sublimis is usually undisturbed and left for later use as an abductor of the thumb, and the middle finger sublimis is split into two, supplying one slip to the middle finger and one to the ring finger. Sometimes the index finger sublimis also is left in position to add strength to the pinch. In these cases the middle finger tendon is split into three slips, one for each of the ring, middle and index fingers.

The tension of the tendon at the time of suture is such that with the wrist straight and the finger straight the tendon is held about half way between the slack position and the fully stretched position. A lower tension is used for very mobile fingers.

The tourniquet is released before the wound is closed and haemostasis is achieved. The palmar wound is drained by a fine polythene tube. The hand is immobilised in a light plaster for three weeks with the wrist straight and the metacarpo-phalangeal joints flexed to a right angle and the interphalangeal joints nearly straight.

In high ulnar palsy the ulnar-supplied half of the profundus muscle is paralysed as well as the intrinsics. If tests show that the profundus tendons to the ring and little fingers do not move with the profundus to the middle and index fingers (they often do move together even though the ulnar half is paralysed), then the profundus tendons are exposed in the forearm and the ulnar-innervated and median-innervated tendons sutured side-to-side. If this is not done, the removal of the sublimis from the ring and little fingers leaves them very weak.

MATERIAL

This is a follow-up study of 150 operations on 150 hands, with a total of 564 clawed fingers. Most of the patients had a complete low ulnar palsy and some had a high ulnar palsy, paralysing part of the flexor digitorum profundus and flexor carpi ulnaris as well as the intrinsic muscles. Most had in addition a complete low median palsy. In most cases of pure ulnar palsy, there was clawing of two fingers only, but in a few there was clawing also of the index and in some cases of the middle finger in spite of unparalysed lumbrical muscles. It seems clear that the interosseous muscles sometimes play the major rather than the minor part in the so-called " lumbrical " action of the fingers.

The paralysis in each case was due to leprosy. We are not able to judge how much of the success or failure of our operations may be attributed to the patient's disease. In the discussion of certain complications reference is made to the patient's disease or anaesthesia. In general, we may say that healing is sometimes rather slower than normal, perhaps because of the gross malnutrition that is common among these friendless and destitute people. On the other hand, post-operative physiotherapy is definitely easier, because exercises are done with an enthusiasm that is not inhibited by pain.

PREPARATION

All the patients have at least partial anaesthesia of their hands. This leads to a great deal of neglected injury, burns and sepsis. A long pre-operative programme aimed at mobilisation of joints and healing of secondary sepsis has been imperative. Operation has always been delayed until a week after all upper limb wounds have been healed soundly enough to allow scrubbing of the healed skin with a brush. Hands have frequently been

operated upon in the presence of an unhealed ulcer on the foot, providing the ulcer has been clean and that it has been kept covered by an occlusive dressing. In these cases penicillin cover has been provided during and after the operation.

SELECTION OF CASES FOR OPERATION

In general, patients have been operated upon when they have felt the need for it because of apparent deformity and loss of function.

The following factors have delayed or contra-indicated tendon transfer operation: 1) Very recent paralysis. In some cases delay has been advised in the hope that recovery might take place. Significant recovery after more than six months has been very unusual. 2) Open wounds and sores (see above). 3) Stiff joints. Physiotherapy and splinting are continued until repeated measurements indicate that improvement of joint mobility has ceased. In a few cases in which there was rigid limitation of extension of the order of 90 degrees, an interphalangeal arthrodesis in the position of function has been offered instead of tendon transfer. When skin tightness or scar seemed to be the factor limiting extension, a full-thickness skin graft on the front of the finger preceded the tendon transfer. These cases are included in the series. In all other cases tendon transfers were done even if passive movement was still limited after physiotherapy. The patient was warned that his post-operative movement was not likely to be better than his pre-operative passive movement. 4) Delays of up to a year have been unavoidable in many cases because the demand for treatment has been so great that waiting lists have been very long.

Apart from these factors there has been no selection of cases for operation.

SELECTION OF CASES FOR FOLLOW-UP STUDY

In calling patients back for follow-up study, the only selection has been geographical. As the Hand Unit has become well known in the East, patients have come from thousands of miles away. Many of these patients are poor, and could ill afford to travel again to satisfy our scientific curiosity. We have therefore only called back patients who live within a certain radius, so that travel would not impose too much hardship. This geographical limit should not affect the validity of the follow-up.

TABLE I

COMPARISON OF SMALL GROUP FOLLOW-UP WITH LARGE GROUP

Group	Number of patients	Excellent (*per cent*)	Good (*per cent*)	Fair (*per cent*)	Poor (*per cent*)
Small (97 per cent follow-up) (Madras-Vellore)	62	14	41	40	5
Large (60 per cent follow-up)	112	17	47	32	4

Letters were sent out to 184 patients requesting a follow-up visit: 112 patients replied and came for study of their hands (150 hands operated upon). This follow-up rate is poor by western standards but better than most attempts at follow-up in India. Extreme poverty, lack of ability to read and write, and change of address are some of the causes.

We tried to compensate for the incompleteness of the follow-up in this way. We chose two towns, Madras and Vellore, where many of our patients live, and made an intensive drive to see every single post-operative patient in these towns. This campaign resulted in the examination of sixty-two patients out of sixty-four. The only patients not seen were two who had changed their address and could not be traced.

FIG. 4

Measurement of " assisted " angle. The base of the protractor is pressed against the proximal segment of the finger, limiting metacarpo-phalangeal extension. The patient now extends the interphalangeal joint and the angle is measured.

This small group has been analysed in the same way as the large group and the comparison is shown in Table I. It will be seen that the distribution of success and failure is much the same in the small group with 97 per cent follow-up as in the larger group with 60 per cent follow-up.

METHOD OF ASSESSMENT

Patients operated upon before 1950 have not been included because of a change in the method of assessment. Since that time every case has been assessed in three ways. These are angle measurement, grasp assessment and photography.

Angle measurement—A protractor with a swinging arm is used, and the proximal interphalangeal joint is measured under the following conditions.

Unassisted extension—The patient has his elbow on the table, forearm upright, wrist straight and metacarpo-phalangeal joints voluntarily flexed. He now tries to extend the interphalangeal joints. While he is trying, his best angle is measured, without the protractor touching the finger. The angle by which he fails to reach 180 degrees is recorded as his " unassisted angle."

Assisted extension—With his hand in the same position, the protractor edge is pressed on the back of the proximal phalanx to hold the metacarpo-phalangeal joint in flexion. The patient again tries to extend the interphalangeal joints, and the new angle, usually a better one, is measured and recorded as his " assisted angle " (Fig. 4). This assisted angle is a measure of the ability of the long extensor muscles to extend the interphalangeal joint when the metacarpo-phalangeal joint is stabilised in flexion.

Passive extension—The examiner grasps the finger and tries gently to pull it straight. The angle by which he fails is recorded as the angle of " contracture." If the assisted angle is very different from the contracture angle, it suggests a defect in the extensor tendon or expansion.

Grasp—This assessment was planned as a functional test. It is a measure of the ability of the patient to reach out and surround an object with his fingers. A standard set of cylinders has been prepared, of diameters ranging from a quarter of an inch to five inches, standing on bases of equal size (Fig. 5). The patient is instructed to grasp and lift up each cylinder between one finger and his palm. The thumb is held in extension out of the way. The biggest diameter of cylinder that the patient can grasp and lift is his " grasp index " for that finger.

This is a useful functional test, but we have not recorded its results in this paper because a serious fallacy was discovered in its use. Some patients soon found that they would get better grades if they moistened their hands than if they were quite dry and slippery (sweating is abolished in denervated hands). Thus, many patients have grasp indices that improve with learning the trick. Since discovering this trick we have wetted all hands before testing. However, the new grades are not comparable with the old.

Photography—We have tried to get a standard photographic record that means something in terms of function. Too often photographs are static, and one is not informed about what the patient is trying to do. Every hand is photographed in six standard positions before operation, and again in the same six positions after operation. It is again photographed in the same six positions at a later follow-up examination (Fig. 6). The patient has a chart

set up in front of him and is told to imitate the pictures on the chart. The photographer also demonstrates with his own hand the position he is to attempt. The six standard positions are: 1) " Hold your hand quite straight at all joints." 2) " Bend at the metacarpo-phalangeal joints and straighten all interphalangeal joints." 3) " Close your fist." 4) " Hold up your thumb at right angles to your hand." 5) " Pinch firmly between index finger and thumb." 6) " Bring your thumb across your palm to the base of the little finger." The photographs include a card with date and number.

FIG. 5

Wooden cylinders for assessing grasp index. It is important that the cylinders should not be fixed or stabilised for the patient. Otherwise he will use the cylinders as a fulcrum and extend his fingers passively.

RESULTS

It is not easy to group together a mass of figures of angles so that they mean something intelligible in terms of success and failure. In this study we have grouped the results as Excellent, Good, Fair and Poor.

The division is bound to be arbitrary and to depend upon our own conception of what we are trying to achieve. It also depends upon what one considers it possible to achieve. For example, it could be argued that it is not reasonable to expect a tendon transfer to move a joint beyond its pre-operative passive range. Therefore, an " excellent " result would be to produce active movement through the whole range of pre-operative passive movement. This is reasonable, but our later results have sometimes shown better-than-excellent results by this standard.

We have chosen in this study to work to absolute standards and not to call a result excellent unless full range has been obtained, however bad the contracture at the time of operation. We have analysed separately the results of operation on different pre-operative types of hands. Results have been analysed to show: 1) The ability of the patient to open his hand fully; 2) the ability of the patient to close his fist fully; 3) the restoration of the correct mechanics of closing the hand (lumbrical movement); 4) absence of abnormal lateral deviation; 5) the patient's own opinion; and 6) the summation of all the above in an overall impression.

THE OPEN HAND ASSESSMENT

To score " excellent " a patient, with hand previously clawed, must be able to open his hand absolutely straight with no single degree of residual flexion at the proximal interphalangeal joint. In position 1 of the standard diagrams for photographs he is allowed to attempt this movement freely, but in position 2 and during measurement he has the restriction that he is not allowed to extend the metacarpo-phalangeal joint while extending the interphalangeal

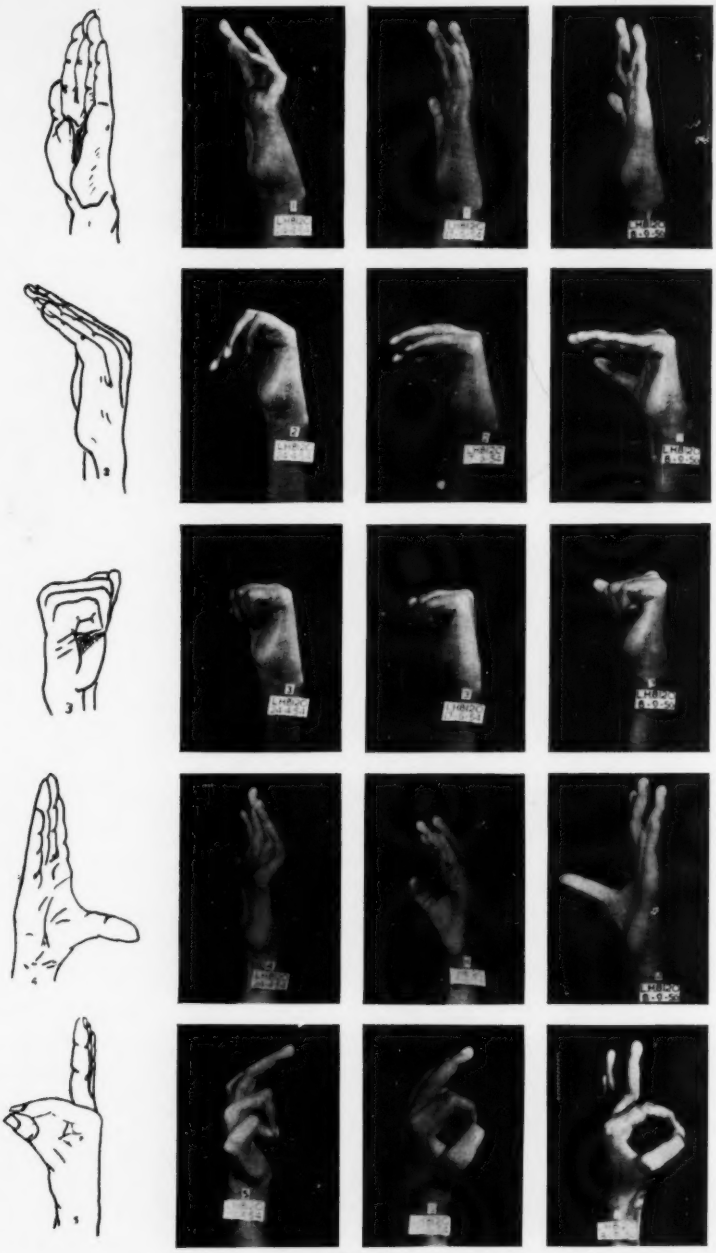

FIG. 6

A typical photographic record. Every patient has exactly this type of photographic record. Column 1, diagrams. Column 2, before operation. Column 3, after operation. Column 4, follow-up (two years later). Notice how the results improve with time. In row 2, illustrating metacarpo-phalangeal flexion with interphalangeal extension, the post-operative result might be classed as good. In the later follow-up it would be excellent if it were not for commencing " intrinsic plus " deformity. In row 3, illustrating the closed fist, the post-operative photograph shows some residual stiffness. A later follow-up shows a normal fist. In row 5, the later follow-up demonstrates the " intrinsic plus " deformity of the middle finger. This patient has also had an abductor replacement operation for his thumb. (Action of the thumb has not been considered in this publication, and the relevant photographs are therefore omitted.)

joints—that is, it has to be a true " lumbrical action." The title to excellence is lost if the finger bends backwards (" more than straight-") on attempting to straighten the finger, or if there is significant ulnar or radial deviation of the finger on straightening.

To score " good " the hand should open out enough for all ordinary function, and enough to appear normal at rest. A normal resting hand may be 30 degrees flexed when measured along the dorsum. It is uncommon to require more than 150 degrees of opening at the interphalangeal joints in grasping the largest objects. To score " good " in our series a finger must open out to at least 150 degrees unassisted. A " good " finger may show perceptible but not gross terminal joint flexion, or it may show slight lateral deviation if it can be fully and normally straightened, but if it shows the slightest limitation of extension *and* has lateral deviation, then it is classed as " fair."

To score " fair " a finger must show improvement over pre-operative figures, and must extend to 120 degrees without lateral deviation. A fully straight finger scores only " fair " if there is a definite lateral deviation, or if it bends backwards into marked " intrinsic plus."

Any finger that does not score " fair " even if it is better than before operation is classed as " poor."

Table II is an analysis of the success of the sublimis transfer to produce a fully open hand with straight, undeviated fingers: 73 per cent of fingers have scored a good or excellent result. This may be further analysed in an attempt to understand the causes of failure and to be able to predict the degree of probable success in any given case.

TABLE II

OPEN HAND ASSESSMENT

Finger	Excellent (*per cent*)	Good (*per cent*)	Fair (*per cent*)	Poor (*per cent*)
Index (130)	29	48	21	2
Middle (134)	32	43	23	2
Ring (150)	36	39	21	4
Little (150)	26	38	30	6
Average	31	42	24	3

Fingers that were stiff before operation showed a much higher proportion of extension limitation after operation than the mobile fingers. This is not surprising. Further analysis shows that 76 per cent of all patients achieved a post-operative unassisted angle that was as good as, or better than, the pre-operative assisted angle. Ninety per cent showed a post-operative angle that was within 20 degrees of the pre-operative assisted angle. The failures (10 per cent) as judged by this standard were further studied, and in an unselected group of five cases in which there was a post-operative contracture more gross than the pre-operative assisted angle exploration was carried out. In every case it was found that the stumps of the sublimis tendons left behind in the flexor sheath had grown across the interphalangeal joint and attached themselves to the sheath, proximal to the joint. They thus formed a sort of bowstring across the joint, preventing extension. On cutting and excising the bowstring the joint could be extended. This complication has been predicted by Bunnell in his writings. We have found that it has occurred less frequently since we have taken care to divide the sublimis exactly at its insertion.

Apart from this complication, it appears that really the only cause of failure to produce full extension by this operation is the presence of pre-operative contracture or pre-operative defect in the continuity of the dorsal expansion (Fig. 7). This later defect is sometimes present in lepromatous cases, and also occurs as a result of old injury or infection on the dorsum of

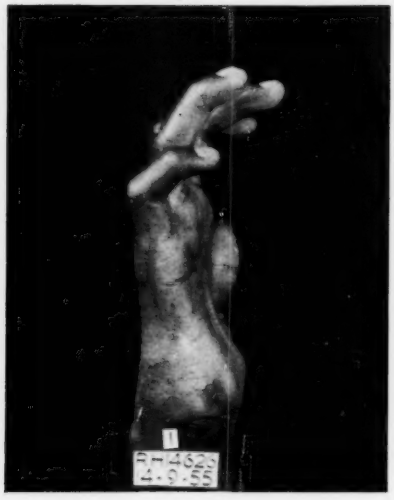

FIG. 7

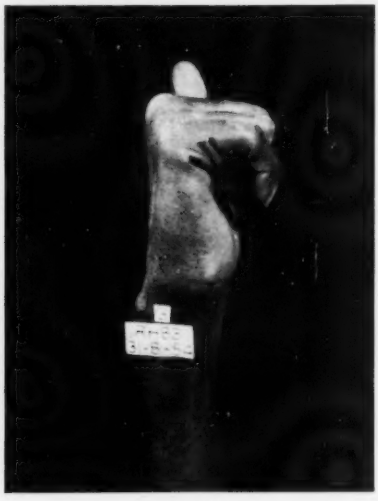

FIG. 8

Figure 7—Incomplete extension of the interphalangeal joints in a hand which had pre-operative contractures. This is a common complication. Figure 8—Imperfect closure of the fist after operation in a patient who before operation had ulnar profundus weakness.

the finger. Such a defect can be assumed to be present when the pre-operative " assisted " angle is very different from the " contracture " angle. The defect must be repaired or the operation will be a failure.

In Table III we have grouped our cases according to their pre-operative mobility. *Hypermobile* implies a good finger with joints that will bend backwards slightly on passive

TABLE III

STATE OF FINGERS BEFORE OPERATION

Finger	Hypermobile (*per cent*)	Mobile (*per cent*)	Defective (*per cent*)	Contracted	
				Mild (*per cent*)	Marked (*per cent*)
Index (130)	8	44	22	17	9
Middle (134)	14	32	34	10	10
Ring (150)	12	30	31	17	10
Little (150)	4	34	35	17	10
Average	9	35	31	15	10

pressure. Such fingers are very common in India where slim, mobile fingers are highly prized. Finger gymnastics form a common part of Indian classical dancing. This dancing demands supple, fluid finger movements which most westerners find impossible to imitate. The *mobile* group includes fingers that could be fully straightened passively. The *defective* group comprised

FIG. 9

FIG. 10

Figure 9—Radial deviation of the fingers. An occasional complication after the sublimis has been sutured to the radial side of the finger. Figure 10—Terminal joint flexion. This occurs in almost every sublimis replacement operation after a year or two.

FIG. 11

FIG. 12

Figure 11—Moderate degree of " intrinsic plus." Hyperextension of the proximal interphalangeal joint and flexion of the terminal joint. This complication is fairly common in mobile hands. Figure 12—Severe degree of " intrinsic plus." This hand in the first year after operation was classed as an excellent result. In the following two years it has developed an ugly and disabling deformity. This degree of " intrinsic plus " is uncommon.

fingers with a full range of passive movement but with a failure in the assisted angle—that is, defect in the dorsal expansion. A *mild contracture* was classed as a lack of passive extension less than 30 degrees. A *marked contracture* was one of more than 30 degrees.

Complications—The " intrinsic plus " deformity is a very interesting one, and its management deserves separate consideration, but a few points must be mentioned here. The name " intrinsic plus " was first used by Bunnell to describe the effect on the hand of an ischaemic contracture of the intrinsic muscles. The features of the condition (Figs. 10 to 12) are as follows: 1) the proximal interphalangeal joint is hyperextended. 2) If the metacarpo-phalangeal joint is held in extension it becomes impossible to flex the proximal interphalangeal joint, even passively. This is the " intrinsic plus sign."

If a sublimis tendon is removed from its insertion in an otherwise normal finger (as in cases where it is to be used as an abductor of the thumb), there often follows a slight deformity marked by a tendency to flexion of the terminal joint and a slight hyperextension at the proximal interphalangeal joint. This deformity never goes on to a fully developed " intrinsic plus " and the interphalangeal joints can be fully flexed passively, even with the metacarpo-phalangeal joints extended. If, however, the sublimis is transferred to the lumbrical insertion, as for intrinsic palsy, a very powerful muscle that was previously a flexor now becomes an extensor of the same joint and leaves that joint with no prime flexor. The profundus muscle takes over the flexor function, but is now an opponent of the sublimis, with which it previously acted synergistically. Re-education of the sublimis and profundus to act reciprocally after the Stiles-Bunnell operation is very difficult. In many cases true reciprocal action never occurs, even though lumbrical action is achieved. If the tendon transfer is made with the sublimis at neutral tension the operation is a failure. If the sublimis is sutured at higher tension than the profundus the operation is a success in that the claw hand is corrected but there seems to be a continued tonus of the sublimis as a background to all finger movement. During closure of the fingers the profundus seems to have to overcome the resistance of the sublimis at the proximal interphalangeal joint before that joint will bend. It succeeds because the mechanical advantage of the flexor tendons at that joint is greater than that of the lateral band.

If the finger is a stout and stable one this muscle conflict does not seem to matter, and if there is some degree of stiffness in the clawed position there may be definite advantage in this continuous corrective pull by a powerful muscle. In a flexible, mobile finger, however, we regularly see a year-by-year tendency to develop hyperextension of the proximal interphalangeal joint and flexion of the terminal joint. If the patient keeps his fingers mobile by exercises and passive movement he may avoid the second feature of " intrinsic plus," the inability to flex the interphalangeal joint even passively when the metacarpo-phalangeal joints are extended. In the absence of such regular movements, the full " intrinsic plus " picture may be developed.

Considered functionally, the " intrinsic plus " hand is fairly useful, and far better than the claw hand that it has replaced. It is ugly, however, and a definite source of weakness, especially in pinch against the thumb (Fig. 12). The seriousness of this deformity was not recognised early because it is seldom noticeable during the first year. The worst cases are seen in the third and fourth years, and most really mobile hands develop at least a mild degree of it after a few years. The deformity is correctable to some extent. We have found that Littler's operation is satisfactory for these cases, but it needs to be supplemented by a tenodesis of the profundus tendon in the middle segment of the finger, with the terminal joint nearly extended, or else the deformity will recur. (This tenodesis would not be necessary in the contracture cases for which Littler's operation was first designed.)

Comment—As this complication occurs in the best and most mobile hands and those that should carry the best prognosis, we have felt it right to abandon the sublimis transfer operation completely for mobile hands during the past year. The operation is probably still the best for the claw hand with contracture because it provides a very powerful corrective, but for mobile

hands it should be displaced by Fowler's operation or by a new operation developed in this unit. We now use free grafts from the extensor carpi radialis brevis. Neither of these operations requires the removal of the sublimis and neither of them is followed by " intrinsic plus " deformity. An analysis of the results of these operations will be published shortly.

We are in a position to say, however, that Fowler's operation is not as good as the Stiles-Bunnell operation for the stiff hand, and it is sometimes disappointing for a few months after operation. The results improve with time, however, especially if the tendon is sutured under fairly high tension (enough to make metacarpo-phalangeal extension difficult in the early post-operative phase), and if care is taken to provide adequate extensor communis action for the little finger, after removal of the extensor digiti minimi.

Our own operation uses the same principle as the Fowler's procedure, in that the new tendon is passed from the dorsum of the hand through the interosseous space, anterior to the transverse metacarpal ligament and sutured to the lumbrical insertion. We use the extensor carpi radialis brevis as the motor muscle and extend its tendon with a four-tailed free graft. The action of a wrist extensor can very easily develop a natural synergism with lumbrical movement. In this operation, also, the action of the hand improves with time. In all our hand reconstructions so far the most perfect approximations to normal finger action have followed this new procedure.

Lateral deviation (Fig. 9)—Abduction and adduction movements of the fingers are functions of the intrinsic muscles. To produce an " excellent " result one should perhaps restore these movements also.

In Bunnell's account of his operation he suggested that the sublimis tendons might be split so that each tendon is attached only to the radial, or only to the ulnar side of adjacent fingers. In this way lateral movement might be restored. It was an ingenious suggestion, but he did not state whether he had ever actually achieved this object. We tried this method a few times some years ago and gave it up because abduction and adduction movements were not obtained. As we looked at the operative field and saw split tendon-slips criss-crossing each other in the palm without intervening soft tissue, it seemed improbable that each slip would move independently of the others. It may be that re-education was at fault. We would be glad to hear of the experience of others. Since 1951 we have been transferring only one sublimis slip to each finger and attaching it to the radial side of the dorsal expansion.

We are satisfied with this method for these reasons: 1) It obviates the need for four incisions on the fingers and shortens operating and tourniquet time; 2) it saves a sublimis tendon which can be used for restoring opposition and abduction to the thumb; 3) it allows another sublimis to be left in the little finger in case of profundus weakness, or in the index finger to strengthen its power of pinch.

On reviewing our cases on a long-term basis we find that 19 per cent show a significant radial deviation and 4 per cent deviate enough to give a deformed appearance. The reason we first chose the radial-side insertion was that it seemed reasonable to have the index finger stabilised on the radial-side to resist the tendency of the thumb to push it medially in pinching.

It has often been stressed that if the first dorsal interosseous muscle is weak a radial-side muscle transfer to the index finger is needed to reinforce the pinch by restoring abduction to that finger.

We have found that one of the disabilities in hands that have been reconstructed after ulnar-median palsy is that the index and middle fingers tend to separate from each other. The anaesthetic tip of the thumb slips in between the index and middle fingers. We have therefore recently begun to insert the index finger sublimis transfer into the ulnar side of the index finger and all the other sublimis slips into the radial side of the other fingers. This has kept the index and middle fingers together and made a very good tripod pinch between thumb, index and long fingers. It also gives a much better appearance to the hand as a whole. The effect of this change on the strength of the pinch will be analysed in a later communication.

The change in insertion is too recent to affect the results in this study, which represents the results of radial-side insertion of the transferred tendon.

CLOSED FIST ANALYSIS

Most patients with claw hand can close their fingers fully before operation except when profundus weakness in the ring and little fingers makes it difficult to flex the terminal phalanges (Fig. 8).

If the fingers cannot close after operation the failure must be due to the operation. Sometimes it may be due to loss of flexion power owing to the transference of the sublimis from its usual place. This is true only of those cases in which there is an additional profundus weakness in two fingers.

An " excellent " category implies a tight fist, with the finger tips fully tucked into the base of each finger. A knitting needle must be grasped and held firmly in the curve of the finger. A " good " assessment means that the finger closes fully but not tightly enough to hold a needle in its curve. " Fair " means that a gap is visible between base of finger and tip but the tip meets the palm farther down. " Poor " means that the finger tip does not meet the palm (Table IV).

TABLE IV

CLOSED FIST

Excellent (*per cent*)	Good (*per cent*)	Fair (*per cent*)	Poor (*per cent*)
39	33	23	5

MECHANISM OF CLOSING

This is a vitally important assessment so far as function is concerned. Results were graded as follows: *Excellent*—Starting from the position of maximal straightness of that finger (even if that is not excellent), the patient can flex the finger first at the metacarpo-phalangeal joints and can complete its metacarpo-phalangeal flexion before the interphalangeal joints begin to flex.

TABLE V

MECHANISM OF CLOSING

Excellent (*per cent*)	Good (*per cent*)	Fair (*per cent*)	Poor (*per cent*)
57	36	5	2

A finger that cannot be fully straightened but which closes with the correct sequence of movement is more useful than a straight finger that closes its interphalangeal joints first when beginning to grasp.

Good—One in which interphalangeal flexion begins just before metacarpo-phalangeal flexion is complete.

Fair—One in which interphalangeal flexion begins and continues along with metacarpo-phalangeal flexion. " Fair " is quite satisfactory for most activity. In fact, it is the mechanism used in the normal hand for grasping small objects. However, it represents a failure to reach a defined standard after operation.

Poor—Metacarpo-phalangeal flexion is delayed behind interphalangeal flexion. The results are shown in Table V.

It will be noticed that the Stiles-Bunnell procedure gives a very good mechanism of closing. A defect in some of these hands which we have not recorded is that the patient cannot close his interphalangeal joints before the metacarpo-phalangeal joints even if he wants to (latent form of " intrinsic plus "). It is associated with the loss of the sublimis from its normal situation. This defect is noticed in typing and piano playing.

DISCUSSION

In reviewing the statistics of the results of the sublimis transfer operation one may feel it has been highly successful. Three-quarters of all cases have given an excellent or good result considered in terms of the open hand, irrespective of the fact that many patients have had pre-operative contracture. The correct mechanism of closing has been restored in more than 90 per cent of cases. One may feel that these figures would be hard to better with any other operation.

However, as we look back on these 150 cases and also on the many other hands that we have seen after operation but which we were not able to re-examine for this study, we do not feel satisfied.

The reason for the remarkable success of the operation is also the source of its greatest weakness. A very powerful muscle, with a big amplitude, like the sublimis digitorum, is used to do the work of a very small muscle, the lumbrical, which has a short range of action. The sublimis transfer, therefore, nearly always achieves its purpose. As time goes on, however, it often more than achieves it and produces secondary deformities. Conversely, the absence of the sublimis from its normal situation produces a weakness in pinch and to a lesser extent in grasp that is significant. We feel that we are now in a position to lay down definite indications for the use of the Stiles-Bunnell operation.

In all cases in which there is a significant contracture at the proximal interphalangeal joint and in which the contracture cannot be fully overcome before operation, the sublimis transfer is the operation of choice. Its powerful corrective effect may produce results that are better than could be predicted from the limited pre-operative range of movement. In stable hands with no range of passive hyperextension of the interphalangeal joints a sublimis transfer under moderate tension will usually give a good result although an operation which avoids the removal of the sublimis tendon would give a stronger and more useful hand.

For hypermobile, flexible fingers the sublimis transfer is contra-indicated. For this type of hand better results will be achieved by Fowler's operation or by the four-tailed graft from the extensor carpi radialis brevis referred to earlier.

SUMMARY

1. The intrinsic paralysis that occurs in leprosy has been treated by the sublimis transfer of Stiles and Bunnell for the past nine years. Since 1951 300 hands have been operated upon, and 150 patients selected geographically have been followed up in this study.

2. The patients have been assessed by a standard method involving: 1) Measurement of range of movement of the interphalangeal joint (unassisted movement, assisted active movement and passive movement); 2) grasp index; and 3) photographs of each hand in six standard positions.

3. *Assessment of the open hand*—The Stiles-Bunnell procedure is effective in achieving a fully open hand: 73 per cent of the fingers scored good or excellent results. A defect in the operation is that it sometimes hyperextends the interphalangeal joint, producing an " intrinsic plus " hand.

4. *Assessment of sequence of joint flexion*—The Stiles-Bunnell operation restores satisfactory mechanism of closure of the hand in 93 per cent of cases—that is, the metacarpo-phalangeal joints flex before the interphalangeal joints.

5. *The closed fist assessment*—About 30 per cent of patients had some defect in the complete closure of the fist after operation. In 5 per cent of cases the fingers did not reach the palm after operation.

6. *Complications*—The " intrinsic plus " defect is commonest in the best and most mobile hands. This is a late complication which gets worse in succeeding years. It can be corrected by Littler's operation together with a profundus tenodesis in the middle segment of the finger. Lateral deviation of fingers due to radial-side attachment of the transferred tendon can be avoided by ulnar-side attachment of the tendon used for the index finger. Bowstringing of the sublimis stump in the flexor sheath may be avoided by division of the sublimis at its insertion. Weakness of grasp and pinch from loss of sublimis may be avoided by using only one or two sublimis tendons split into several strands. The index finger sublimis should be left in position.

7. It is concluded that the sublimis transfer of Stiles and Bunnell is a very powerful corrective of intrinsic paralysis of the fingers. Its chief defect is that it is too powerful and produces the opposite deformity. For this reason the use of this operation should be restricted to fingers in which there is some limitation of passive extension. For fully mobile fingers an operation should be selected which does not remove the sublimis from its normal position.

Most of these operations have been performed by a series of assistants and trainees in hand surgery. I wish to thank them for the enthusiasm and meticulous care in record keeping which has made this study possible. I also wish to record my appreciation of the sterling work of our records clerk, Mr Furness, who has travelled many miles in seeking out changed addresses. I would like to thank Mr Guy Pulvertaft for his helpful criticism of this article.

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A STUDY OF THE END-RESULTS OF COMPRESSION ARTHRODESIS OF THE KNEE

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This paper is a review of the results of compression arthrodesis of the knee performed during the ten-year period from 1946 to 1956. It was decided to exclude three cases of Charcot's disease because this condition seems to offer special difficulties unrelated to the general problem of osseous union.

The documents of 171 adult cases were available for study, and it is interesting to record immediately that only two failures were encountered, so giving a success rate for compression arthrodesis of the knee of 98·8 per cent. The average time from operation to discarding plaster and walking free of external splintage, in the 169 successful cases, was nine weeks.

The operations were performed by ten different surgeons and therefore the details of operative technique and post-operative management showed minor variations; for this reason only the broadest conclusions can be drawn. In all cases the joint surfaces were resected with a saw. Compression was applied by transfixing the bones above and below the resected joint with 4-millimetre Steinmann nails and attaching compression clamps to the projecting ends (Key 1932, Charnley 1948). In most cases external splintage by Thomas's splint or plaster cylinder was employed. In a small number of cases no external splint was used. In most cases compression was maintained for four weeks, but in a few the compression was maintained for six weeks. A plaster cylinder was applied when the compression nails were removed, and in most cases this was retained for four weeks. If consolidation was not complete at the end of this time the plaster cylinder was reapplied and retained until clinical union was sound. Weight bearing was permitted during the first week after application of the plaster. We consider the most important statistic to be the time after operation when the plaster was finally discarded.

Specially detailed operation notes were available in forty-nine of the cases which had been operated on by the principal author (J. C.). In these it was known that a compression force of approximately 100 lb. had been employed in accordance with the method of estimating the deflection of the nails described elsewhere (Charnley 1953). Although equally high forces were used by many of the other surgeons, this was not thought to be an invariable rule. Therefore an attempt was made to see whether the results in the cases in which it was known that high pressure was used showed any significant trend towards quicker union in comparison with the remaining 120 successful cases.

CLINICAL MATERIAL

The main clinical groups comprised cases of osteoarthritis, rheumatoid arthritis and tuberculosis, as indicated in Table I. Seven knees with miscellaneous pathology were also arthrodesed and are included in this Table.

BONE DENSITY

In thirty-three non-tuberculous cases the notes made specific reference to the quality of the bone encountered at operation—that is, to the presence of normal density or to the presence of a notable degree of osteoporosis. In these non-tuberculous cases the osteoporosis was almost always the result of rheumatoid arthritis. Fifteen patients with osteoporosis were walking free of plaster in an average time of 8·2 weeks after operation; eighteen patients with bone of normal density were walking free of plaster 7·6 weeks after operation.

COAPTATION IN RELATION TO UNION

Radiographs were not available in all of the 171 cases, but in those which were available twenty-two cases were discovered in which the apposition of the cut bone surfaces was incomplete. In these the anterior or the lateral views showed gaping of the cut surfaces so

TABLE I

ANALYSIS OF CLINICAL MATERIAL (169 cases)

Number of cases	Pathology	Average time to walking free (*weeks*)
57	Osteoarthritis	8·5
37	Rheumatoid arthritis	9·0
68	Tuberculosis (adult)	9·5
2	Old deformed ankylosis	9·5
2	Spastic hemiplegia	9·0
1	Old compound fracture knee	8·0
1	Osteomyelitis of patella	8·0
1	Poliomyelitis (weak quadriceps)	8·0

that intimate apposition was present over a reduced area. Union failed to occur in one case, which is reported later as presenting one of the two failures in the series. In all the remaining twenty-one cases union occurred; and the average time between operation and walking free of plaster was 9·4 weeks. Compared with the average time of nine weeks for union in the whole series, the delay from defective coaptation was thus very slight.

TABLE II

COMPLICATIONS

Complication	Number of cases
Mild pin-track infection	6
Venous thrombosis	5
Supracondylar fracture of femur	4
Wound sepsis	2
Pin broken	2
Foot-drop (recovered)	1
Sinus of patellar remnant	1

CLINICAL UNION AT THE END OF COMPRESSION

The state of clinical union was recorded at the time of removal of the compression apparatus and at the time of application of the ambulatory plaster cylinder in 145 cases. The compression apparatus was removed, and the walking plaster was applied, at an average of four weeks after operation. Of these 145 knees 88·2 per cent were recorded as clinically united at four weeks. By " clinical union " we mean that no trace of movement, or of fibrous " give," could be detected when the arthrodesis was subjected to passive strain.

When the compression clamps were removed in seventeen cases it was recorded that slight movement was still present in the arthrodesis. In all of these cases clinical union developed while the patient was walking in a plaster cylinder in an average time of ten weeks from the time of operation.

COMPLICATIONS

There was no mortality. The complications are enumerated in Table II. In the six cases of mild pin-track infection the tracks all healed without trouble. The two wound infections also resolved under antibiotics and sound osseous union occurred. The four cases of supracondylar fracture were caused by using a hammer to drive the nail; no displacement of the incomplete fracture occurred and union took place at the same time as arthrodesis.

THE FAILURES

Two patients failed to achieve osseous union, which makes a failure rate of 1·2 per cent. In one case the failure was because one of the compression nails broke. The cause of failure in the other case is unknown, but it is recorded that the apposition of the cut bone surfaces was defective.

DISCUSSION

The most interesting result of this investigation is the success rate and the average time for clinical union of the whole series.

The successful results in twenty-one of the twenty-two cases in which coaptation was imperfect are of great theoretical interest when the reasons for the success of the compression technique are debated. It is often considered that the success of compression arthrodesis is the result merely of simple mechanical factors—namely, the intimate coaptation produced by pressure and the immobilisation which follows automatically from the accurate coaptation of plane surfaces of considerable area. But compression can produce rigid immobilisation only if the plane surfaces of the resected joints are in contact over the whole area. If the surfaces gape even slightly the rigidity of fixation cannot be greater than that provided by the external fixation. In only one of the twenty-two cases in which apposition was defective did union fail to occur. The combination of defective apposition and defective rigidity certainly prolonged the average time for union, but it did so only very slightly. This supports the idea that absolute immobilisation is not a primary factor in the success of compression arthrodesis of the knee, but as a secondary factor absolute immobilisation is a valuable adjunct. This reasoning supports the idea that absolute immobilisation is essential only when osteogenesis is defective or absent in one element taking part in any union, as for instance in bone grafting. When both the elements taking part in any union have a full blood supply and normal powers of osteogenesis, these experiences with compression arthrodesis of the knee suggest that the degree of immobilisation necessary for success is something less than absolute.

In comparison with normal bone the slightly longer time required to secure clinical union in the osteoporotic bone of rheumatoid arthritis is interesting in view of the common opinion that it is easier to arthrodese the knee in rheumatoid arthritis than in most other conditions.

SUMMARY

1. An analysis of 171 cases of compression arthrodesis in the knee is presented.
2. A total success rate of 98·8 per cent was revealed.
3. The average time between operation and walking free of splintage was nine weeks.
4. When the compression was removed, after an average period of four weeks, 88·2 per cent of the knees already showed clinical union.

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THE VALUE OF INTRA-ARTICULAR INJECTIONS IN OSTEOARTHRITIS OF THE KNEE

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Contradictory views have been expressed by different authors about the effect of intra-articular injections in osteoarthritis. Key (1933) actually claimed to have produced osteoarthritis experimentally with agents similar to those later used therapeutically by other observers. It is therefore not surprising that perplexity is felt about the value of these injections.

Waugh (1938) stimulated interest in this form of treatment, using lactic acid with procaine, and this solution has also been investigated by several other authors (Ramamurthi 1947, Sønder 1950). A wide variety of other substances has been used—for example, acid potassium phosphate (Crowe 1944), sodium bicarbonate (Kron 1948), and procaine alone (Baker and Chayen 1948, Melkild 1953). The introduction of the cortisone group of drugs has popularised this form of treatment, and accounts of the use of hydrocortisone have been given by Hollander, Brown, Jessar and Brown (1951), by Bornstein *et al.* (1954), and by Fallet and Lambelet (1955). Ross, Mayer and Shepherd (1958) reported the use of benzyl salicylate. Of all these substances, lactic acid with procaine, procaine alone, and hydrocortisone are still commonly used.

In some reports, results are difficult to interpret because the numbers recorded are small. Kron (1948) had only five cases of osteoarthritis in fifteen patients complaining of painful knees. Andersson and Petersen (1953) considered only eight osteoarthritic knees in their report, and Melkild (1953) only seven. In other accounts, the concurrent use of aids such as splintage, dieting and physiotherapy has obscured the role of intra-articular injections. Baker and Chayen (1948) used rest, analgesics and physiotherapy along with the injections. Desmarais (1952) and Lawrence (1953) used physiotherapy when indicated. These papers are excellent reports on combined therapy, but they do not demonstrate the value of intra-articular injections alone. Many reports lack proper controls. Indeed, only one author could be found whose controls were fully acceptable: Desmarais (1952) used normal saline and mock injections.

With these criticisms in view it is understandable that Wiles (1955) is also of the opinion that no convincing series has yet been published. Accordingly, during the past four years, we have undertaken an investigation to determine the true status of certain intra-articular injections when used alone in the treatment of painful osteoarthritis of the knee. A series of 181 cases is reported. Four different solutions were studied, including normal saline; mock injections were also used.

CLINICAL MATERIAL

The investigation was designed to study the effect of treatment on " primary " osteoarthritis. " Secondary " forms of the condition may not only behave quite unlike the " primary " form, but may also vary among themselves. The following secondary forms of osteoarthritis were excluded: 1) post-traumatic osteoarthritis; 2) internal derangements complicated by osteoarthritis; 3) osteoarthritis with any suggestion of rheumatoid overlay; 4) old infective joint disease, pyogenic or tuberculous, with subsequent osteoarthritis; 5) neuropathic arthritis. The remaining cases of osteoarthritis were accepted for treatment, provided that: 1) pain was present when treatment was begun, and was not showing any tendency to subside; 2) positive radiological evidence of osteoarthritis was present; and 3) treatment had not been given previously.

One joint only has been studied in the investigation to avoid the inaccuracies which may arise in attempting to compare the effects of treatment on different joints. The knee joint was regarded as the most suitable because of its accessibility both for injection and for assessment.

Initial assessment—When the case had been accepted for the study on the criteria mentioned, an initial assessment was made in order to establish a base line for subsequent observations on the joint. For consistency in the method of examination, all assessments throughout the series were carried out by the same observer. The questioning and examination of the patient were conducted in privacy to avoid discussion between patients which might influence their attitude towards treatment. All the relevant clinical features of history, physical signs and radiographic findings were entered on a detailed form, used in conjunction with the Powers-Samas punch card system. The patient was then allotted one of the injections at random, and the same injection was used throughout his treatment. The clinical assessor was ignorant of the particular solution assigned to any patient, and did not himself give any of the injections.

Solutions used for injection—Five forms of injection were agreed upon when the investigation was designed, and at this time also the chemical formulae of the fluid injections were determined. With the exception of the proprietary preparation, the solutions were freshly prepared in the clinical laboratory on the day of injection.

Each solution for injection was given a number from 1 to 5. The numbers corresponding to each of the solutions prepared in the laboratory were known only to the laboratory staff.

The following solutions were chosen as typical of those in common use.

Injection 1. *Lactic acid solution*—N/5 lactic acid 0·2 grammes; novocaine hydrochloride 2·0 grammes; physiological normal saline 55 millilitres; distilled water to 100 millilitres. The pH of this solution was 5·7. The pH of Waugh's (1938) original solution was 5·0. Desmarais (1952) used a solution of pH 5·4, and Waugh (1945) later used a solution of pH 5·8.

Injection 2. *Novocaine solution*—Novocaine hydrochloride 2·0 grammes; physiological normal saline 55 millilitres; distilled water to 100 millilitres. The pH of this solution was 5·9. Novocaine hydrochloride has a constant pH, but that of procaine is variable. Alkaline procaine was used by Desmarais (1952).

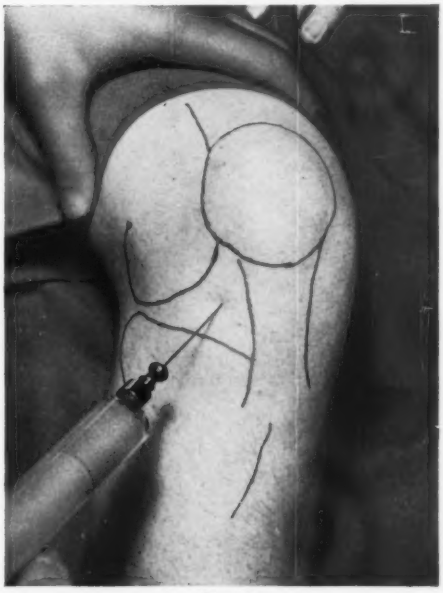

FIG. 1

This illustrates the triangular area through which the joint puncture is made, the needle being directed upwards and medially.

Injection 4. *Hydrocortisone solution*—Two millilitres of a proprietary preparation (containing 25 milligrams of hydrocortisone per millilitre) made up to a standard volume of 10 millilitres with physiological normal saline. The pH was 7·7. Hollander *et al.* (1951) used doses of 25 to 37·5 milligrams of hydrocortisone.

The following controls were used.

Injection 3. *Physiological normal saline solution*—The pH of this solution was 7·1.

Injection 5. *Mock injection* (see below).

Solutions 1 and 2 were sterilised by the Seitz filter technique, and Solution 3 by heat. It was thus ensured that no alteration in the chemical properties of the solutions occurred during sterilisation. The hydrocortisone suspension used in Solution 4 was sterilised by the manufacturers.

In the case of Solutions 1, 2, 3 and 4 a constant volume of 10 millilitres was used.

Technique of injection—A uniform procedure was adopted in order to standardise the method. The patient was seated on the table with the knee flexed to a right angle, and a nurse cleaned the skin with ether soap. Before the towels were applied to the knee the skin was treated by the surgeon with cetyl trimethyl ammonium bromide, and then painted with tincture of iodine. The site selected for injection was the triangular area at the lateral side of the joint bounded by the tibial plateau, the edge of the ligamentum patellae and the curve of the lateral femoral condyle. Local anaesthesia was not used for the skin puncture lest the material enter the joint. This was regarded as particularly important because two of the solutions contained a local anaesthetic. A Number 19 B.W.G. needle was introduced through the centre of the triangle (Fig. 1). A specimen of any fluid aspirated was collected under oil and sent immediately for pH estimation, cell count and bacteriology. The laboratory findings are not relevant to this paper. Ten millilitres of the solution assigned to the patient were then injected into the joint cavity. The puncture was covered by a small sterile dressing, but a supporting bandage was not applied.

To satisfy ourselves about the reliability of the technique a small series of injections was carried out on cadavers. A coloured solution was used, and in each case the fluid was shown to have entered the joint.

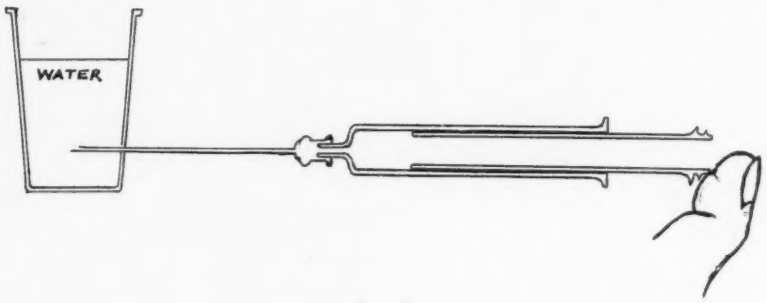

FIG. 2

This shows the principle of the modified syringe used for mock injections. When tested under water as illustrated, no air bubbles or coloured fluid could be expressed into the water in the beaker. (Half scale.)

For the mock injections a special syringe was employed. The hollow plunger of a plastic Vandermic syringe was converted into an open tube by removing the detachable caps from each end. Fluid could thereafter be drawn up by occluding the end of the plunger with the thumb. If the end of the plunger was incompletely occluded it could be depressed without expressing any of the contents of the syringe through the needle. It was fully tested under water through the side of a small plastic beaker (Fig. 2), and also in a small series of cadavers. We were satisfied that, used in this manner, it was not possible for fluid or air to be injected into the joint. The same visual effect was produced by this device as by fluid injection.

The allotted injection was given to the patient on five occasions at intervals of two weeks. All the patients were treated as out-patients and allowed to pursue their ordinary activities. There was no case of accidental joint infection in this series.

Reviews—Each patient was reviewed on two occasions, six weeks and six months after the end of treatment.

First review—This consisted of a complete clinical re-examination by the same examiner and under identical conditions as in the initial assessment. A form was completed, but the examiner did not have access to the results of the initial assessment. Lest the examiner be influenced, the patient's own opinion was recorded only after the examination had been completed.

Second review—This consisted of a record of the patient's own opinion of the condition of the knee six months after the first review. Its object was to discover how many patients were still satisfied with the effects of the treatment.

RESULTS

A total of 202 patients with primary osteoarthritis of the knee began treatment, but twenty-one of these defaulted. The reasons for the defections were: prompt relief after one injection (five cases); acute non-infective reaction after injection (two cases); dissatisfaction with treatment (three cases); emigration (two cases); untraced (nine cases). Since these patients did not complete the full course of treatment it is not possible to include them in the series.

The remaining 181 patients completed the full course of treatment, with the following results.

FIRST REVIEW

Patients' opinions—The opinions expressed by the patients when seen six weeks after the end of their treatment are shown in Table I. The response was the same in men and women in the case of each injection studied. Statistically, there is no significant difference between the

TABLE I
PATIENTS' OPINIONS SIX WEEKS AFTER CESSATION OF TREATMENT

Opinion	Injection										Total number
	1 Lactic acid + Novocaine		2 Novocaine		3 Saline		4 Hydrocortisone		5 Mock		
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	
Improved	30	88·2	34	91·9	28	77·8	31	83·8	30	81·1	153
Unchanged	4		3		8		5		6		26
Worse	—		—		—		1		1		2
Total	34		37		36		37		37		181

TABLE II
OBJECTIVE ASSESSMENT SIX WEEKS AFTER CESSATION OF TREATMENT (MEN)

Assessment	Injection										Total
	1 Lactic acid + Novocaine		2 Novocaine		3 Saline		4 Hydrocortisone		5 Mock		
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	
Improved	11	91·7	10	91·0	8	72·7	9	81·8	12	85·7	50
Unchanged	—		—		—		1		2		3
Worse	1		1		3		1		—		6
Total	12		11		11		11		14		59

percentages of improvement. Altogether, 153 out of 181 patients (84·5 per cent) stated that they had improved.

Objective assessment—Numerous physical signs related to osteoarthritis were taken into account, but a preliminary study of a random sample of all the data collected left us in no

TABLE III

OBJECTIVE ASSESSMENT SIX WEEKS AFTER CESSATION OF TREATMENT (WOMEN)

Assessment	Injection										Total
	1 Lactic acid + Novocaine		2 Novocaine		3 Saline		4 Hydrocortisone		5 Mock		
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	
Improved	14	63·6	20	76·9	18	72·0	18	69·2	13	56·5	83
Unchanged	5		3		5		6		4		23
Worse	3		3		2		2		6		16
Total	22		26		25		26		23		122

doubt that, because of their capacity to be influenced by treatment, the following were the most reliable guides on which to base an accurate clinical assessment: 1) joint tenderness; 2) range of movement; 3) presence or absence of limp; 4) effusion; 5) quadriceps power.

Three gradings had been agreed upon, and one grade was assigned to each of these features, depending on whether it had improved (+1), remained unchanged (0) or worsened (−1). The summation of these points indicated the clinical state of the joint relative to the initial assessment. The results are shown in Tables II and III. Men and women have been presented separately because the percentage of men showing improvement is significantly different from the percentage of women.

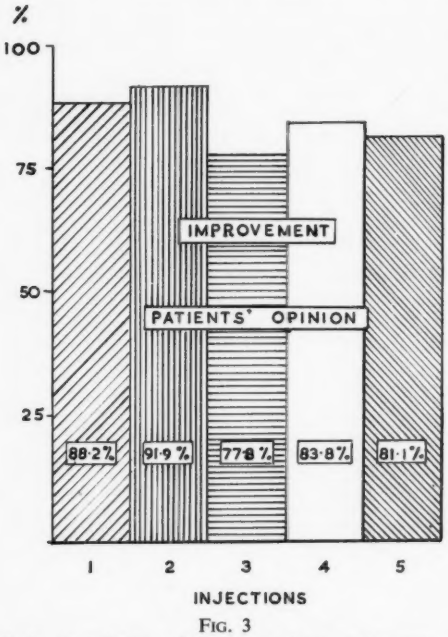

FIG. 3

Patients' opinions of treatment (men and women combined). The chart shows the proportion of patients claiming improvement six weeks after treatment ended. Only improvements are illustrated. Statistically, there is no significant difference among the three therapeutic agents and the two controls.

The difference among the percentage of clinical improvement in the men is not statistically significant. Out of fifty-nine patients fifty (84·7 per cent) showed improvement. In the women also the difference among the percentage improved with the different injections is not statistically significant. Eighty-three out of 122 patients (68 per cent) showed improvement. Statistical analysis of the overall percentage improvement in men (84·7 per cent) and in women (68 per cent) shows that there is a significant difference ($x^2 = 5{\cdot}7$, $P < 0{\cdot}05$ for one degree of freedom).

A diagrammatic summary of the patients' opinions showing the comparative effects of the different injections is given in Figure 3. The objective findings in the men and in the women are similarly represented in Figure 4.

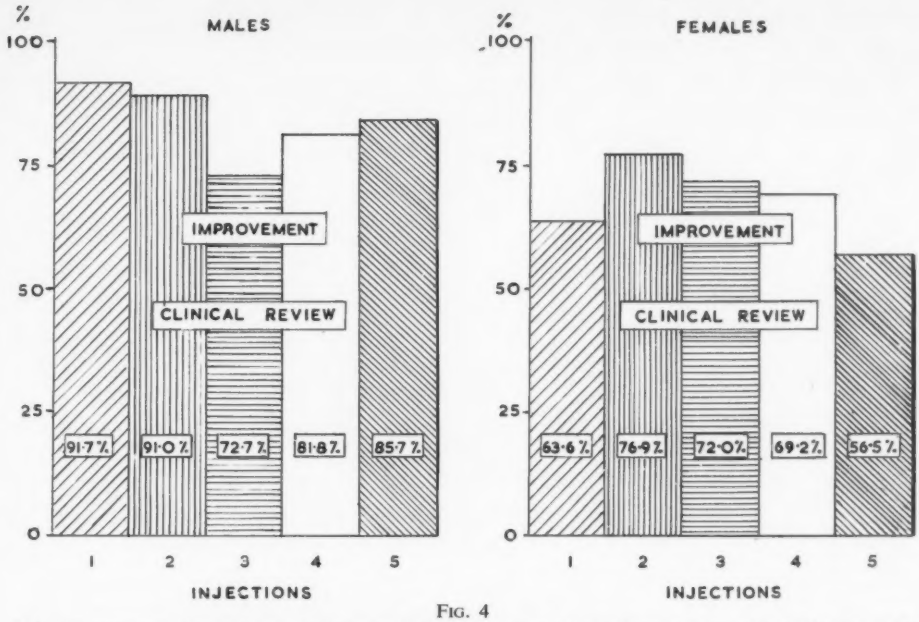

FIG. 4

Objective assessment in men (*left*) and women (*right*). The chart shows the proportion of joints judged to be clinically improved six weeks after the end of treatment. Only improvements are illustrated. In neither men nor women was any particular injection significantly different from the others.

SECOND REVIEW

Six months after the first review the patients' opinions were again recorded. In this interval six patients died of intercurrent disease and eight did not continue their co-operation. The opinions of the remaining 167 patients are shown in Table IV.

TABLE IV

PATIENTS' OPINIONS SIX MONTHS AFTER CESSATION OF TREATMENT

Opinion	Injection					Total
	1 Lactic acid +Novocaine	2 Novocaine	3 Saline	4 Hydrocortisone	5 Mock	
Improved	29	30	32	30	24	145
Unchanged	2	—	1	1	4	8
Worse	1	4	1	3	5	14
Total	32	34	34	34	33	167

The opinion of each individual patient at the second review was compared with his first opinion. There was agreement in 133 cases out of 167, or 79·6 per cent (Table V). It is clear that six months after the first review there was still no demonstrable difference of statistical importance among the injections.

TABLE V

AGREEMENT BETWEEN FIRST AND SECOND OPINIONS (MEN AND WOMEN)

	Injection					Total
	1 Lactic acid + Novocaine	2 Novocaine	3 Saline	4 Hydrocortisone	5 Mock	
Number of patients agreeing in first and second opinions	30	28	25	27	23	133
Total	32	34	34	34	33	167
Percentage of agreements .	93·8	82·4	73·5	79·4	69·7	79·6

DISCUSSION

The results of this inquiry show that the behaviour of a joint may be influenced by intra-articular injections. The series has been studied from two different points of view, that of the patient and that of the clinical assessor. From both approaches there is no significant difference in the effects of the three therapeutic agents investigated. It is illuminating to find that either of the controls, one of which was a mock injection, was just as effective as any of the three solutions.

Since similar results are obtained with weak acids, a mildly alkaline preparation, and a neutral solution, we cannot subscribe to the acidification theory of Waugh. The claim that intra-articular anaesthesia may be a factor in the relief of painful osteoarthritis is also not tenable, as there was a similar percentage of successes with the injections that did not contain a local anaesthetic. Nor can we attribute any effects produced to the volume of fluid injected, for mock injections proved to be as beneficial as the solutions.

Three features are common to the procedure adopted in each group—namely, joint puncture, the witnessing by the patient of a full aseptic ritual for each injection, and the impression of interest and personal attention given in each case. Each of these features produces a certain psychological response, depending upon the outlook of the patient.

In any investigation into the effect of therapy a proportion of the patients will respond favourably, simply on account of the " placebo " effect. This may amount to as much as one-third of the patients (Wayne 1956). Injection is a form of administration which enhances this effect, and raises the proportion of favourable responses even higher (Leslie 1954). Osteoarthritis is, moreover, a condition that is characterised by natural remissions. A number of otherwise eligible patients were excluded from the series because they were undergoing such a spontaneous remission. It is possible that a proportion of the patients who were admitted to the series underwent a remission during the course of their treatment, thus increasing the percentage of successes.

From the point of view of the assessor, there was found an appreciable objective improvement, which was fairly evenly distributed. Presumably, this indicates a more natural and confident use of the joint, and is a reflection of the change in outlook of the patient after the injections. The objective assessment also shows that the percentage of improvement was higher in men than in women. Between the men and the assessor agreement was almost complete, but more women expressed satisfaction than the assessor was prepared to accept on clinical grounds. The inference is that women are more susceptible to suggestion in this form of treatment, and here again the psychological element must be taken into account.

In this study most patients in each group expressed satisfaction with their treatment. This does not depend at all upon the injection of any particular substance into the joint, but rather upon the psychological atmosphere created. Provided that one acknowledges such a

basis for the improvement procured, the use of joint puncture can be accepted as a reasonable placebo in the care of osteoarthritis. It follows that, if puncture is decided upon, the least noxious and most economical substance (normal saline) or none at all (mock injection) should be used.

The introduction of new substances does not appear to have influenced the results of intra-articular injection therapy in osteoarthritis. Many substances enjoy considerable popularity in this form of treatment often without the proper controls to justify their use. We believe that such agents for which specific therapeutic effects are claimed should be admitted as advances in treatment only after stringently controlled clinical trials.

SUMMARY

1. Criticisms are expressed of previous reports on the use of intra-articular injections in the treatment of osteoarthritis of the knee.
2. A series of 181 patients with primary osteoarthritis of the knee treated by certain intra-articular injections is reported. Three solutions in common use were studied; normal saline and mock injections served as controls.
3. Irrespective of the injection used, including the controls, no significant difference in the effects was demonstrated in the results.
4. The place of intra-articular injection therapy in osteoarthritis is discussed. Attention is drawn to the psychological implications.

We wish to thank Mr Alexander Miller for the interest he has shown, and for affording us the facilities to carry out this investigation. We are also grateful to Mr R. Barnes and Mr J. Patrick for their co-operation. The help and advice we have received from Dr W. B. Davis and Dr J. E. Craik, of the Clinical Laboratory of the Victoria Infirmary, has been invaluable. We are most indebted to Dr R. A. Robb, Senior Lecturer in Statistics, Mathematics Department, University of Glasgow, for the great assistance he has given us in the compilation of the statistics.

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TRANSPOSITION OF GLUTEUS MAXIMUS, TENSOR FASCIAE LATAE AND ILIO-TIBIAL BAND FOR PARALYSIS OF LATERAL ABDOMINAL MUSCLES IN CHILDREN AFTER POLIOMYELITIS

A Preliminary Report

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The assessment of twenty-four patients in whom tensor fasciae latae and ilio-tibial band transposition was performed for strengthening the lateral abdominal muscles after poliomyelitis (Clark and Axer 1956) revealed that better results were obtained when the muscle was active and strong. In order to obtain a more powerful motor for the musculo-tendinous unit advantage was taken of the twofold insertion of the gluteus maximus: only one-fourth of the gluteus maximus—the deep fibres of its caudal half—gain insertion into the femur; the other three-quarters of the muscle—that is, all its superficial fibres and the deep fibres of its cranial half—are inserted into the ilio-tibial tract (Gray's Anatomy 1946, Last 1954, Henry 1945). The gluteus maximus in other words is a tensor of the fascia lata in addition to being an extensor and lateral rotator of the hip.

"The pelvic deltoid" of Henry—Between the tensor fasciae latae and the gluteus maximus the pelvic part of the fascia lata (ilio-tibial tract) is situated and was described by Henry (1945) as "a special piece of tract—the proximal expanse which hides gluteus medius, and occupies the gap between the maximus and tensor muscles. Indeed we may regard these three (the tensor, tract and maximus) as figuring a pelvic deltoid . . ." (Fig. 2).

It is the "pelvic deltoid" of Henry which has been used in this operation, since August 1954, as the motor for the musculo-tendinous unit, with gratifying results.

OPERATION

The operation is carried out in much the same way as the transposition of the tensor fasciae latae for paralysis of the lateral abdominal muscles (Clark and Axer 1956), except for the addition of the proximal part of the gluteus maximus to the musculo-tendinous unit. The patient is placed on the operation table in the lateral posture, with the side to be operated upon uppermost. The greatest possible correction of lumbar scoliosis is secured by an appropriate manipulation of the table. The skin incision starts below the anterior part of the iliac crest, curves in its proximal part slightly behind the greater trochanter in order to facilitate the exposure of the gluteus maximus, and continues along the outer aspect of the thigh to end at the level of the knee (Fig. 1). The dissection of the three to five centimetres wide strip of the ilio-tibial band begins in the region of the lateral femoral condyle and is continued towards the greater trochanter. When the gluteus maximus is reached its cranial half (or third) is separated from the rest of the muscle and mobilised, but left attached to the ilio-tibial band. This division of the gluteus maximus is carried out through its whole thickness far enough posteriorly to allow for the unobstructed redirection of the cranial part of the muscle obliquely and upwards towards the ribs together with the ilio-tibial band (Figs. 2 and 3). Care is taken not to injure the nerve to the muscle: the gluteus maximus is supplied by the inferior gluteal nerve, which enters the deep surface of the muscle nearer to its origin than to its insertion (Last 1954).

In none of the eight cases reported here was it necessary to carry the division of the muscle so far posteriorly as to endanger its nerve supply.

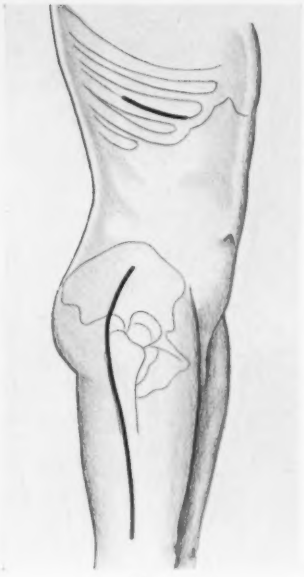

FIG. 1

FIG. 2

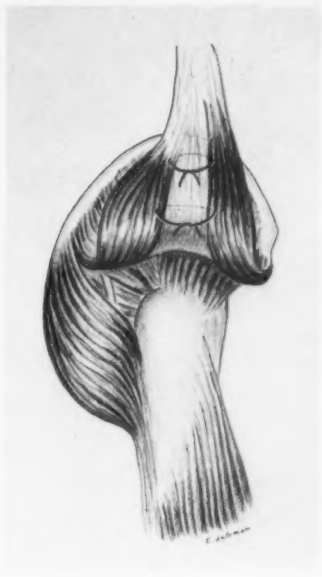

FIG. 3

Technique of operation. Figure 1—Skin incisions. Figure 2—The " pelvic deltoid " of Henry with the outline of dissection of the musculo-tendinous unit for transposition. Figure 3—The dissected musculo-tendinous unit ready for transposition to the rib. The gluteus maximus and tensor fasciae latae are approximated with catgut sutures to form one motor unit.

Freeing of the ilio-tibial band and of the tensor fasciae latae is completed in the same manner as in tensor fasciae latae transplantation (Clark and Axer 1956). A musculo-tendinous unit consisting of the cranial part of the gluteus maximus, the tensor fasciae latae and the ilio-tibial band (the " pelvic deltoid " of Henry) is raised and ready for transposition to the chosen rib. Electrical stimulation of both muscles separately is done at that stage and the distance for which the free end of the ilio-tibial band moves with each contraction of the particular muscle is measured (Table II).

The tensor fasciae latae and the proximal part of the gluteus maximus are approximated by a few catgut sutures and in that manner one bulky motor unit is created (Fig. 3). The free end of the ilio-tibial band is attached under moderate tension to the chosen rib after being pulled through the previously prepared subcutaneous tunnel, joining the proximal end of the thigh incision with that situated over the rib. Closure of the wounds is followed by application of a double hip spica, with the greatest possible correction of the scoliosis.

Post-operative treatment—Active extension exercises of the hip are added to abduction and flexion movements in order to elicit contractions of the gluteus maximus and tensor fasciae latae. These movements are later synchronised with active elevation of the pelvis on the same side. If both the gluteus maximus and the tensor fasciae latae are active a continuous stabilisation of the thoraco-pelvic relationship is achieved in practically all phases of gait, because the transplant is under tension during both extension (gluteus maximus) and flexion (tensor fasciae latae) of the hip.

DISCUSSION

In Table I the indications for and results of the operation are presented. All the eight children had poliomyelitis during their first or second year of life, the average age at the onset being one year and two months.

TABLE I

INDICATIONS FOR OPERATION AND RESULTS

Case number	Date of onset of poliomyelitis	Age at onset *Years*	*Months*	Date of operation	Age at operation *Years*	*Months*	Interval between onset and operation *Years*	*Months*	Indications for operation	Follow-up *Years*	*Months*	Results
1	May 1952	0	7	October 1954	3	0	2	5	Left lateral abdominals weak; left pelvic tilt; scoliosis	3	0	Pelvis level; scoliosis unchanged; transplant active
2	1952	about 1	0	January 1955	4	0	about 3	0	Left lateral abdominals weak; left pelvic tilt; left lower extremity longer; thoraco-pelvic instability, walked with difficulty; scoliosis	2	11	Pelvis level; lower extremities of equal length; walks very well (no braces or crutches); scoliosis unchanged; transplant active
3	October 1952	1	2	February 1955	3	6	2	4	Right lateral abdominals weak; right pelvic tilt; right lower extremity longer; scoliosis (partly fixed; Milwaukee brace since 1953)	2	9	Pelvis level; lower extremities of equal length; scoliosis worse (no Milwaukee brace since operation); transplant active
4	June 1953	0	8	August 1955	2	10	2	2	Right lateral abdominals weak; right pelvic tilt; right lower extremity longer; scoliosis	2	5	Pelvic tilt improved; lower extremities of equal length; scoliosis unchanged; transplant active but weak
5	May 1952	2	0	August 1955	5	0	3	0	Left lateral abdominals weak; left pelvic tilt; left lower extremity longer; scoliosis	2	5	Pelvis level; lower extremities of equal length; scoliosis unchanged; transplant active
6	August 1950	2	6	August 1955	7	6	5	0	Right lateral abdominals weak; right pelvic tilt; right lower extremity longer; scoliosis	2	5	Pelvis level; lower extremities of equal length; walks (braces); scoliosis improved; transplant active
7	September 1954	1	2	September 1955	2	2	1	0	Right lateral abdominals weak; right pelvic obliquity; right lower extremity longer; scoliosis	2	2	Pelvis level; lower extremities of equal length; scoliosis unchanged; transplant active but weak
8	October 1953	0	6	September 1955	2	5	1	11	Right lateral abdominals weak; right pelvic tilt; right lower extremity longer; scoliosis	2	2	Pelvic tilt improved (in hanging); lower extremities of equal length; scoliosis improved; transplant active and corrects pelvic tilt entirely

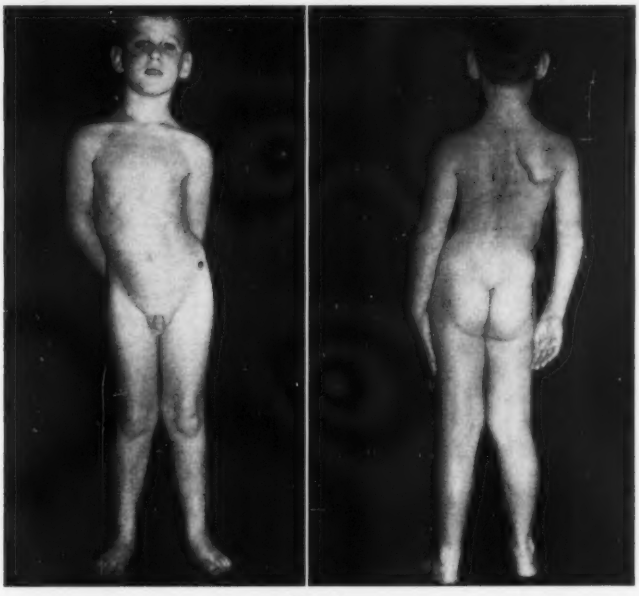

FIG. 4

Boy aged six with paralysis of the lateral abdominal muscles on the left side. Photographs show the boy before operation. Note the uncompensated paralytic scoliosis, with marked shift of the upper trunk to the right.

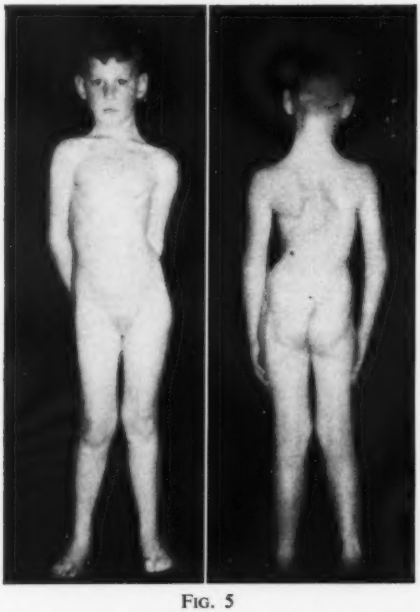

FIG. 5

Figure 5—Same child after operation. Improved posture.

FIG. 6

Figure 6—Same child after operation, sitting.

TABLE II

RESULTS RELATED TO GRADING OF MUSCLES BEFORE OPERATION AND ELECTRICAL RESPONSES AT OPERATION

Case number	Pre-operative grading*		Excursion on electrical stimulation at operation (*centimetres*)†		Post-operative grading of gluteus maximus (hip extension)	Result
	Gluteus maximus (hip extension)	Tensor fasciae latae	Gluteus maximus	Tensor fasciae latae		
1	2	1	3	0	3−	Active
2	4−	4+	2	1	4−	Active
3	4	4	2	3	3+	Active
4	3−	1+	1	0	3−	Active (weak)
5	3−	4−	2·5	0	3	Active
6	3+	3+	3·5	2	3+	Active
7	2−	1	1	0	2−	Active (weak)
8	3+	3+	2	0	3+	Active

* According to international grading: from 0 (paralysed) to 5 (normal).

† The distance (in centimetres) through which the free end of the ilio-tibial band moved on direct electrical (faradic) stimulation of the motor (muscle) with a bipolar electrode, after the dissection of the unit was completed.

The oldest child at the operation was seven years and six months of age, the youngest two years and two months. The average age at the operation was three years and ten months. The shortest interval between the onset of paralysis and operation was one year, the longest five years, the average being two years and seven months.

In all eight children scoliosis was present at the time of the operation: in one child it became worse, in two it improved, and in five it remained unchanged after the operation. A follow-up ranging from two years and two months to three years is too short to allow conclusions to be drawn on the durability of the apparently beneficial effect of this operation on paralytic scoliosis. Nevertheless, it seems that in most cases the progress of the deformity was checked or retarded. In Figure 4 a boy aged six at the operation in December 1956 (not included in this report) is shown before the transplantation of gluteus maximus. A marked shift of the upper trunk to the right due to decompensated paralytic scoliosis is obvious. In Figure 5 the same boy is shown in a very similar stance fifteen months after the operation which was performed on the left side and resulted in a definite improvement in posture. In Figure 6 the same boy is shown sitting.

Pelvic obliquity was eliminated in six cases and improved in two. The discrepancy in the length of the lower extremities was corrected in all patients. Thoraco-pelvic stability was improved in all the children, and in two instances the improvement was exceptionally beneficial, as indicated in the following case reports.

CASE REPORTS

Case 2—A boy, who for three years after the onset of poliomyelitis could walk only with great difficulty, circumducting the right lower limb widely and falling frequently because of a pronounced weakness of the lateral abdominal muscles and quadratus lumborum on the right side, was operated upon at the age of four (three years after the onset of paralysis), and he is now able to run.

Case 6—The boy in this case could not walk or stand for five years after the onset of paralysis, mainly because his right lateral abdominal muscles and quadratus lumborum were so weak that a considerable pelvic tilt developed, causing a discrepancy of three centimetres in the length of the lower extremities and a scoliosis. With the gluteus maximus and tensor fasciae latae transplantation performed at the age of seven years and six months the deformities were corrected and enough thoraco-pelvic stability was restored to allow the boy to walk with the help of apparatus.

FIG. 7

FIG. 8

FIG. 9

Case 1—Effect of a strong motor unit. Figure 7—Before operation. Considerable pelvic tilt in relaxed suspension. Figure 8—After operation. Pelvic tilt corrected in relaxed suspension. Figure 9—On active hip extension pelvic tilt is over-corrected by action of the musculo-tendinous unit consisting of gluteus maximus and ilio-tibial band transferred to the ninth rib. On electrical stimulation of the motor during the operation the tensor fasciae latae was found to be completely paralysed, but the gluteus maximus contracted vigorously and moved the free end of the ilio-tibial band for a distance of three centimetres.

With an active, strong transplant the child is able to lift the pelvis against gravity by synchronising that movement with extension of the hip (by the gluteus maximus) (Figs. 7 to 9), or with flexion-abduction, if the tensor fasciae latae is active.

In Figures 10 and 11 a girl of twenty (not included in this report) is shown who was operated upon on the left side in July 1957. A strong gluteus maximus transplant can be seen bulging under the skin in walking during the phase of weight bearing on the left leg (Fig. 11), contributing to improvement of thoraco-pelvic stability and facilitating the gait. In Figure 12 the same girl is shown sitting; the transplant helps to balance the thorax over the pelvis.

With a transplant that is only moderately strong or even " weak," the patient may not be able to raise the pelvis high enough to allow for a comfortable " swing-through " of the lower extremity during walking (Figs. 13 and 14), but the musculo-tendinous unit would improve the thoraco-pelvic stability (Fig. 15). In that respect its action recalls that of a weak " hamstrings-into-patella " transplant, insufficient so far as the carrying out of a full extension of the knee against gravity is concerned, but strong enough for effective stabilisation of the knee during walking.

The ultimate strength and efficiency of the transplant is not only directly proportional to the excursion of the free end of the ilio-tibial band on faradic stimulation of its motor during operation (Table II), but also to the " vigorousness " of the contraction of the muscle. However, this factor was omitted from the Table because it could hardly be presented in an objective manner. On the whole, those transplants were ultimately strong in which the contractions of both muscles or of the gluteus maximus alone caused the free end of the ilio-tibial band to move for a distance of not less than three centimetres.*

In all eight instances the transplant was found " active " after the operation.† It has to be emphasised that in five of the eight cases the tensor fasciae latae was found at operation

* For each operation the same electrical stimulator was used and the same strength of faradic current was applied to different areas of the muscle. The longest excursion of the free end of the ilio-tibial band was noted.

† In the previously published series of twenty-four cases of transplantation of the tensor fasciae latae (Clark and Axer 1956) the musculo-tendinous unit was found to be " passive " in seven instances.

FIG. 10

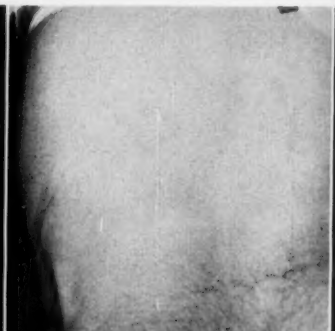

FIG. 11

FIG. 12

Figure 10—A strong left gluteus maximus transplant demonstrated in a girl of twenty. In Figure 11 the transplant is seen bulging under the skin and contributing to the improvement of thoraco-pelvic stability. In Figure 12 the same girl is shown sitting.

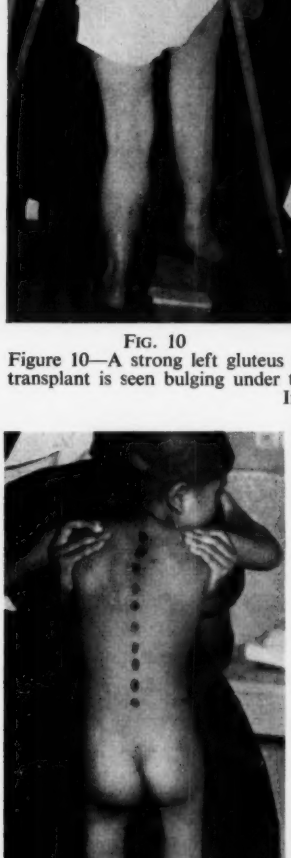

FIG. 13

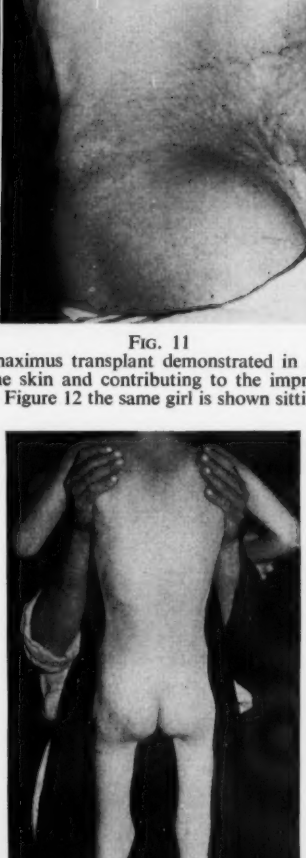

FIG. 14

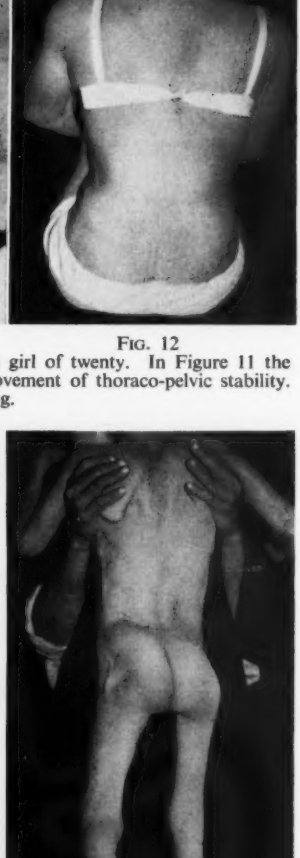

FIG. 15

Case 5—Effect of transposition of a moderately strong muscle. Figure 13—Before operation. Pelvic tilt in relaxed suspension. Figure 14—After operation. Slight pelvic tilt still present in relaxed suspension. Figure 15—On active hip extension pelvic tilt is corrected but not over-corrected. The musculo-tendinous unit consisting of gluteus maximus and ilio-tibial band can be seen in action bulging under the skin. On electrical stimulation of the motor during the operation the tensor fasciae latae was found to be completely paralysed, but contractions of the gluteus maximus were of moderate strength and moved the free end of the ilio-tibial band for a distance of 2·5 centimetres.

to be completely paralysed, as it did not react at all to the direct faradic stimulation with a bipolar electrode (Table II). However, in none of these five cases was the tensor fasciae graded " 0 " before the operation; in Cases 5 and 8 it was even charted 4 and 3 respectively. That proves that the clinical estimation of the strength of the tensor fasciae latae in small children may be very misleading and therefore cannot be relied upon. The pre-operative grading of the gluteus maximus, on the other hand, was found to correspond with the observations made at operation. The advantage of using the gluteus maximus for the transplantation in conjunction with the tensor fasciae latae, or alone if the latter muscle is paralysed, is obvious.

It was further observed that the pre-operative grading of hip extension remained practically unchanged in all cases after the operation, although one would expect a weakening of hip extension after removal of half of the gluteus maximus from its insertion. The anatomy of the gluteus maximus, already referred to, may contain the explanation for that phenomenon: the deep fibres of the caudal half of the muscle are the only ones that gain insertion directly into the femur, all the rest of the muscle being inserted into the fascia lata. Those particular muscle fibres may be regarded with reasonable probability as the primary extensors of the hip. They remain undisturbed after this operation. However, this observation requires confirmation on a larger series of cases.

SUMMARY

1. An operation for strengthening the lateral abdominal muscles in children after poliomyelitis is described. It consists of transposition of the proximal part of the gluteus maximus, the tensor fasciae latae and the ilio-tibial band (" the pelvic deltoid " of Henry) to a chosen rib.

2. The results of this operation in eight consecutive cases of paralytic scoliosis, pelvic obliquity and thoraco-pelvic instability are assessed.

3. A " strong " motor allows the child to lift the pelvis against gravity, whereas with a " weak " motor the child is unable to do so efficiently. However, even a " weak " musculo-tendinous unit helps invariably in restoring the thoraco-pelvic stability, just as a weak " hamstring-into-patella " transplant stabilises the knee.

4. Those motors (gluteus maximus with or without tensor fasciae latae) that contract vigorously and move the free end of the ilio-tibial band for at least three centimetres on direct faradic stimulation with a bipolar electrode during the operation become ultimately strong and most efficient.

5. The unreliability of the clinical test of tensor fasciae latae in small children is discussed, and the advantage of using the gluteus maximus as the motor for the musculo-tendinous unit is emphasised.

6. Using the proximal half (or less) of the gluteus maximus for strengthening the lateral abdominal muscles does not seem to affect appreciably the strength of hip extension. This phenomenon may be explained with reasonable probability by the existence of a twofold insertion of that muscle.

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THE MANAGEMENT OF PATHOLOGICAL FRACTURE OF THE MAJOR LONG BONES FROM METASTATIC CANCER

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Pathological fracture of a major long bone occurs in only a small proportion of patients suffering from disseminated cancer. Metastasis to long bones is much less frequent than it is to the flat bones and the vertebral column (Fitts, Roberts and Ravdin 1953). The usual sites of origin of metastases are well known. Those arising in cancer of the breast or bronchus are the most common because of the high incidence of the primary tumours.

It is commonly assumed that a pathological fracture from this cause will heal when treated by simple external splintage. This is a misleading half truth. Fracture through a deposit of low malignancy may indeed heal with such management, but very slowly, and by the time bony union has occurred many patients have passed the stage when they can appreciate the result of the surgeon's care. In fracture through a deposit of higher malignancy non-union is much more likely.

Conservative treatment applied to lesions of the femur cannot be relied upon to produce a reasonable proportion of satisfactory results. When fracture occurs in the humerus the patient need not be kept in bed during conservative treatment. If destruction is extensive, however, nothing short of a plaster shoulder spica will provide adequate immobilisation, and this is a considerable imposition upon the patient, especially when the fracture fails to unite and the splint has to be worn indefinitely.

Most patients suffering long-bone pathological fracture have widespread disease, but it is wrong and unkind to regard this misfortune as a terminal event warranting only the simplest of symptomatic treatment. Recognition of this state of affairs demands the greatest expedition in returning the patient to comfort and mobility, that he may better enjoy his remaining months.

In an effort to achieve this, the routine management of such pathological fractures in the Middlesex Hospital since 1954 has been by internal fixation and radiotherapy. More recently the technique has been extended " prophylactically " to destructive lesions discovered at a stage when fracture has not actually occurred but is feared to be imminent.

CLINICAL MATERIAL

The results of management by internal fixation and radiotherapy in thirty-six consecutive long bone pathological fractures from metastatic cancer in thirty-three patients and of the " prophylactic " use of the same treatment in seven patients have been reviewed. Fourteen patients previously reported by Devas, Dickson and Jelliffe (1956) are included in this series. Of the forty patients reviewed, twenty-nine were women and eleven men. Double fractures were sustained by three patients, one fracturing the necks of both femora and two both femur and humerus. The sites of primary origin, the sex distribution and the site of bone involvement are summarised in Table I.

ROUTINE MANAGEMENT

All fractures were treated by internal fixation at the earliest opportunity. Fractures of the femoral neck and trochanteric region of the femur were fixed by a McKee nail and plate (Fig. 1), and those of the middle third of the femur by an intramedullary nail (Küntscher 1940)

(Fig. 5). Fractures of the upper third of the femur were immobilised either by an intramedullary nail or, in the case of some fractures near the subtrochanteric region where an adequate grip could be obtained for plate screws below the lesion, by a nail and plate. A Rush pin was used for fracture of the humerus (Fig. 2). The fracture site was exposed whenever this proved technically necessary, and the opportunity taken to obtain a biopsy specimen. The aim was to provide sufficiently strong internal splintage to remove the need for external support completely, and this was generally achieved. All patients were given radiotherapy, beginning as soon as discomfort from the operation had settled. When intramedullary fixation had been employed the whole length of the involved bone was irradiated. The tumour dose depended on the radio-sensitivity. If histological examinations showed an anaplastic deposit, or if the

TABLE I

CLINICAL MATERIAL

Site of primary tumour	Total number of lesions	Males	Females	Bone involved			
				Femur			Humerus (shaft)
				Neck and trochanteric region	Shaft		
					Upper third	Middle third	
Carcinoma of breast	19	—	18*	9 (2P)	6	2	2
Carcinoma of bronchus	8	6	2	3 (1P)	1 (P)	4 (1P)	—
Carcinoma of thyroid	2	—	2	2	—	—	—
Carcinoma of rectum	2	—	2	1	—	1	—
Epithelioma of scalp	2	—	1*	—	1	—	1
Malignant angio-endothelioma of naso-pharynx	2	—	1*	1	—	—	1
Carcinoma of kidney	1	1	—	—	—	1	—
Carcinoma of oesophagus	1	1	—	—	—	—	1
Multiple myelomatosis	3	1	2	1	1 (P)	—	1 (P)
Undiscovered	3	2	1	2	1	—	—
Totals	43	11	29	19 (3P)	10 (2P)	8 (1P)	6 (1P)

* Indicates a double lesion in one patient.

(P) Indicates the number of " prophylactic " internal fixations included in the preceding figure.

deposit had come from a primary tumour known to be radio-sensitive, a tumour dose of 2,000 to 3,000 r over one or two weeks was given. If the metastasis came from a well differentiated radio-resistant tumour the dose was larger. It is easier to deliver large doses after internal fixation, because the increased mobility of the patient and the absence of external splints allow the use of several fields around the involved limb. When the primary tumour was hormone-dependent, testosterone or stilboestrol was given, and, in selected cases, the adrenal or pituitary gland was removed. In one case cortisone was used in an effort to depress adrenal function. Mobility in bed was always encouraged immediately after the operation, and when reasonably firm internal fixation had been secured early non weight-bearing walking with crutches was advised. Most patients were walking with crutches within four to six weeks of operation. Patients with upper limb fractures were allowed immediate use of the arm.

RESULTS

Operative deaths—No death was attributable to operation. Six patients (15 per cent) died within six weeks of operation, and necropsy showed the cause of death in each case to be extensive metastatic carcinoma. There was no indication that operative intervention had played a part.

Morbidity from operation—There was no wound sepsis in this series and no evidence of tumour fungation into the wound in those cases where the fracture was exposed. Swelling of the limb was often considerable, but this gradually settled and gave rise to no particular difficulty. Wounds healed in the normal time. No case of pulmonary embolism or fat embolism was encountered (Haebler 1949).

Relief of pain—This was one of the most striking benefits. The pain of the pathological fracture was immediately relieved and any residual discomfort was easily controlled by analgesics.

FIG. 1

Internal fixation enabled this patient to walk despite fractures of both femoral necks, one of which remained ununited.

It was of interest that internal fixation also relieved pain associated with those metastatic deposits that were treated " prophylactically."

Survival time—Twenty-nine patients (72·5 per cent) survived for more than three months after operation, thirteen (32·5 per cent) for more than six months, and five (12·5 per cent) for more than a year. The longest surviving patient lived for three years. In four of the five patients who survived for more than a year the primary tumour was a carcinoma of the breast that was hormone-sensitive. One of these patients had been subjected to bilateral adrenalectomy and oöphorectomy. In the remaining case the primary growth was a carcinoma of the rectum.

Union and function. *Femoral shaft fractures* (fifteen patients)—Four patients died less than a month after operation and did not leave their beds. The remaining eleven patients all walked with crutches, and three eventually with only a stick. Ten showed radiographic evidence of union of the fracture. In the remaining case union is not yet sound, but it is a recent fracture and appears likely to unite.

FIG. 2
Extensive destruction of the humerus from a carcinomatous metastasis. Internal fixation enabled external splints to be dispensed with, and allowed useful function of the arm.

Fractures of the neck and trochanteric region of the femur (sixteen fractures in fifteen patients)—One patient died six weeks after operation. The remaining fourteen patients were able to walk with crutches, and two eventually walked with a single stick. Of the fifteen fractures (bilateral in one instance) in patients surviving more than three months, eleven progressed to radiological union. In the four patients with fractures which did not show radiological union, internal fixation still served a useful purpose in stabilising the fracture. For example, one patient with a fractured femoral neck was thus able to walk with elbow crutches, despite a previous fracture of the other femoral neck (Fig. 1). *Fractures of the humerus* (five patients, two also with fracture of the femur)—One patient died two weeks after operation. Of the remaining four, three progressed to union of the fracture and one, whose fracture was fixed with a Rush nail only after two months of attempted immobilisation in a plaster shoulder spica, failed to unite. In spite of this, the arm functioned quite well for the remaining six months of his life (Fig. 2).

" Prophylactic " group (seven patients)—Three of the patients in this group had destructive lesions of the femoral neck or trochanteric region, and the bone was reinforced by a nail and plate (Fig. 3). One patient died three days after operation with extensive visceral metastases. The other two began to walk with crutches as soon as the wound healed. Both were still alive and walking with crutches, one twenty months and the other four months after operation. In both, the lesion had shown some reconsolidation after radiotherapy.

Prophylactic reinforcement of the femoral shaft with an intramedullary nail was undertaken twice for carcinomatous metastases, one in the upper third and one in the mid-shaft. Both patients were allowed to walk immediately after operation. The lesions failed to consolidate after radiotherapy, but both patients continued to get about comfortably until they died from generalised metastases three and four months after operation. Particular interest attaches to the first of these because a pathological fracture around the nail took place a month after fixation (Figs. 4 and 5). The fracture was symptomless, and the patient continued walking. A third patient had a " prophylactic " nail inserted for extensive destruction of the upper half of the femoral shaft due to myelomatosis. This patient was well and walking normally three months after operation. " Prophylactic " fixation of the humerus was undertaken in another patient with myelomatosis. He lived for only three months after operation, but function of the arm remained satisfactory.

FIG. 3
Reinforcement of a femoral neck weakened by a carcinomatous metastasis.

In summary: excluding the patients treated " prophylactically," twenty-five (83 per cent) of the thirty patients suffering a lower limb fracture survived for more than six weeks and all returned to walking with crutches. Union occurred in four-fifths of these fractures. Four of the five patients with a fracture of the humerus survived to regain a functionally useful arm and three of the fractures united.

Other metastatic deposits at the time of operation—Twenty-seven patients (67·5 per cent) had obvious bone secondaries elsewhere at the time of operation, and many patients without obvious bone deposits were known to have visceral metastases. This is a matter of some importance in view of the theoretical danger of spread of tumour cells by operation.

Surgery of the endocrine glands—One patient was subjected to bilateral oöphorectomy. She was alive six months later but had widespread and increasing bone and soft-tissue deposits. Two patients were subjected to bilateral adrenalectomy and oöphorectomy. One died two

FIG. 4

FIG. 5

Figure 4—Metastasis in upper part of femoral shaft before internal reinforcement.
Figure 5—A month after intramedullary nailing a fracture occurred through the site of the tumour. There were no symptoms.

months later and one was alive and in good health twenty months after operation: this patient was treated for a fracture of the upper third of the femoral shaft through a metastasis from a carcimona of the breast and walked well with only a stick (Figs. 6 and 7). Pituitary ablation was carried out on two occasions: one patient died a month later and the other survived for ten months, during which a pathological fracture of the neck of the femur united.

DISCUSSION

Pathological fracture of a major long bone is a dramatic and distressing manifestation of disseminated cancer. It is surprising that the problem of its palliation has received so little attention in the literature. Hope of long survival after such a mishap is slender: despite radiotherapy, radio-active isotopes, hormone therapy and surgery, only a third of the patients in this series survived for more than six months and only one in eight for more than a year.

Nevertheless the comfort of the patient during this interval is important. Return to mobility and home surroundings contribute materially to this. Such a measure of comfort was afforded to over four-fifths of our patients as a result of management by internal fixation and radiotherapy. In some of the patients who survived for more than six months (one-third of the total) the fractures might have united with conservative treatment, but the other patients would certainly have been condemned to spend the remainder of their days in bed, or perhaps semi-ambulant in a plaster.

Operation was also of value in the six patients who failed to survive for more than six weeks and did not become ambulant. Little upset was caused and there was substantial relief of pain almost at once, with increased comfort and ease of nursing.

FIG. 6

FIG. 7

Figure 6—Metastasis in femur from a carcinoma of the breast. Figure 7—Twenty months after internal fixation and bilateral adrenalectomy and oöphorectomy. The fracture is soundly united.

The danger of disseminating tumour cells either generally or locally is the main criticism of this method of treatment. It has been shown by Peltier (1951) that both local and general dissemination are caused by intramedullary nailing under experimental conditions. It could be argued, however, that pathological fracture itself is at least as potent a cause of tumour cell dissemination. In this series, in which radiotherapy was used to cover the whole of the operation area, there was no evidence of spread into the soft tissues locally or along the medullary canal. In one case there developed what at first appeared to be tumour deposits along the nail, but radiographs of the other femur showed a similar appearance, suggesting that the patient already had generalised disease before the operation. Whether or not any general blood spread is caused is more difficult to determine. In considering this possible danger it is well to remember that before operation these patients usually have either obvious clinical evidence of widespread metastases or a highly malignant tumour with presumptive

generalised microscopical disease. Internal fixation might not be justified in the treatment of a single metastasis from a primary tumour of low grade malignancy carrying a prognosis of several years, but in general the theoretical dangers of dissemination may be ignored.

All fractures through metastatic deposits should be given the benefit of radiotherapy, although some may be relatively radio-resistant. Radiotherapy is made technically easier by the absence of external splints and the increased mobility of the patient after internal fixation. The presence of a metal pin in the treatment field has certain theoretical disadvantages. Using 250 kv. x-rays of about 1–2 mm.Cu. half-value layer some shadowing will occur behind the metal owing to increased differential absorption. This can largely be obviated by the use of two or more opposing fields. In any case, the aim is not necessarily to destroy completely every malignant cell in the affected area but to facilitate union of the fracture and prevent local recurrence over a limited period. Secondary irradiation from the metal will lead to more intensive ionisation in the cells immediately adjacent to the nail, but tissue damage is too localised to give rise to any clinical effects. These objections can be eliminated by using large telecurie or supervoltage units (Wilson 1950).

Although the pathological fracture is quite often little displaced it has proved surprisingly difficult to pass an intramedullary device " blind " except in the " prophylactic " fixations. This is probably explained by the friable nature of the surrounding bone, which makes it easy to create " false passages," and to the induration of the surrounding tissues, which makes exact reduction difficult. We have had no reason to regret exposing the fracture, and we now believe that the most reliable technique is to carry out a limited exposure of the fracture and guide the nail, passed from the proximal end of the femur or humerus, past the fracture under direct vision. This technique has the added advantage of allowing a biopsy specimen to be taken. The practice of disrupting the fracture in order to pass the nail backwards up the proximal fragment, so useful a procedure in dealing with traumatic fractures, is not justifiable when the fracture is through a tumour deposit. The only local factor that limits the use of internal fixation is the absence of sufficient firm bone in either the proximal or the distal fragment to provide an adequate grip for the fixation device. This problem is most likely to be encountered in dealing with fractures of the femoral neck, where the available hold on the head of the femur may be tenuous. A nail and plate has been used in all such lesions to give added security. Even when a completely firm grip on the head seems unlikely the presence of the nail and plate may give sufficient stability to allow the patient to get about in much greater comfort than would otherwise be the case. Little is to be lost in the attempt and it is generally worth while.

In dealing with the shaft of the femur or humerus there is usually enough sound cortical bone to grip the nail firmly. In only one case did we fail to gain a sufficiently good hold below a mid-femoral shaft fracture. Lateral rotation of the lower fragment occurred about the nail a few days after operation, and a Thomas's splint was necessary for four weeks to control rotation until some consolidation had taken place. The ultimate result was satisfactory. In high fractures of the upper third of the femoral shaft the use of a nail and plate has certain advantages over an intramedullary nail, provided there is enough sound bone below the lesion to hold the screws. An intramedullary nail may rotate in an upper fragment that is too short or too friable.

Some shortening took place during healing in most cases, but this was not a serious disadvantage and was easily compensated by shoe adjustment. It is a small price to pay for an early return to active life.

The number of lesions treated "prophylactically" is small, but we consider that the results are encouraging and that this technique has a definite field of usefulness. The decision when a lesion is in imminent danger of fracture is abritrary, but internal reinforcement of the tumorous bone is much easier than internal fixation after fracture has occurred. It causes little upset and early walking may be encouraged with increased confidence. Later it may save

the patient much suffering and inconvenience, as evidenced by the asymptomatic fracture around the nail in a case already mentioned (Figs. 4 and 5). Breaking of the nail is unlikely, for the endurance of the metal is likely to outlast the patient. Substantial relief of pain immediately after " prophylactic " fixation was striking: it may be explained by relief of tension in the lesion or by relief of stress on the bone.

In view of the high rate of union of fractures of the femur it seems disappointing that only five patients were able to give up their crutches. But other factors must be considered in assessing the functional end results. In contrast to patients suffering traumatic fracture, prolonged re-education was not deemed reasonable for patients whose expectation of life was short. Most patients returned home at the earliest opportunity. Many already had other deposits which limited their activities. On the whole it was considered a satisfactory result if the patient could walk again with axillary or elbow crutches, and no particular effort was made to get rid of them except in those few cases promising a particularly good prognosis.

SUMMARY

1. Problems of management of a pathological fracture of a major long bone through a metastatic cancer deposit are outlined. The relatively short life expectancy of these patients is stressed.

2. The results of treatment of thirty-six consecutive fractures of this type by internal fixation and radiotherapy, and of similar treatment used " prophylactically " on seven occasions, are reviewed.

3. Four-fifths of the patients with lower limb fractures became ambulant with crutches and were able to return home.

4. " Prophylactic " internal fixation and radiotherapy appear to be helpful in selected cases.

5. The theoretical dangers and difficulties of the technique are discussed. They are easily surmountable and have probably been over-emphasised in the past.

6. It is concluded that this is the best method at present available for dealing with this difficult problem.

Our thanks are due to Mr Philip Wiles, Mr P. H. Newman, Professor B. W. Windeyer and Miss M. D. Snelling for permission to include patients under their care, and to Mr M. Turney of our Photographic Department for preparing the radiographic prints. We are further indebted to Mr Philip Wiles for his most helpful advice and criticism in preparing this paper.

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POSTERO-LATERAL DISLOCATION OF THE KNEE WITH CAPSULAR INTERPOSITION

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Traumatic dislocation of the knee is uncommon. The force required to produce it is usually severe, and there is often associated injury to the popliteal vessels or nerves. Postero-lateral dislocation differs from other types of dislocation in several respects. It is primarily a rotary dislocation without great displacement, and without associated injury to the vessels or nerves. It is almost always accompanied by button-holing of the medial femoral condyle through the medial capsule, and invagination of the medial [internal lateral; tibial collateral] ligament into the joint. It is irreducible except by open operation.

Invagination of the lateral part of the capsule occasionally complicates medial dislocation of the knee (Smillie 1946) and open operation is required to extract it from the joint, but there is no block to closed reduction of the medial displacement of the tibia. A true lateral dislocation may be difficult to reduce by closed methods, because the tendons of the medial hamstrings are caught in the intercondylar notch; nevertheless, as Böhler (1935) pointed out, reduction can be accomplished if the knee is flexed more than 90 degrees. In postero-lateral dislocation we have found open operation always to be necessary, both to reduce the displacement, and to extract the infolded ligament and capsule. At least seven such cases have been described in the literature (Clarke 1942, Anderson 1943, Griswold 1951, Speed and Knight 1956). In none was the mechanism of injury described. In two of the five cases recorded here the patient was able to give a clear history of severe abduction-medial rotation violence to the knee while the limb was not bearing weight. In the other three a similar force was compatible with the circumstances of the accident. An investigation of the effects of such a force on the knees of cadavers confirms that the constant anatomical features, clinical signs and radiographic appearances are all consistent with this mechanism of injury.

HISTORY AND FINDINGS IN FIVE CASES

History of injury—Every patient gave a history of sudden and severe violence applied to a lower limb; three of them were in road accidents. One, a miner aged thirty-eight, was thrown from his motor-cycle when trying to avoid a van. The rear double wheels of the van ran over his left leg from behind forwards as he lay on the road. The inner wheel passed over the outer side of his foot and ankle, which were protected by a miner's boot, rotating his leg medially and abducting it and throwing him from his left side on to his face. The outer wheel ran over the lower third of the leg. His knee was flexed halfway to a right angle when this occurred. He sustained an undisplaced compound fracture of the left medial malleolus, and a postero-lateral dislocation of the knee. A second patient, a woman railway worker aged forty, was jumping out of the way of a falling wagon door when it struck the outer side of her right knee in mid air, knocking her sideways to the ground and forcing her leg into abduction at the knee joint. The continuing momentum of the door caused it to strike the outer side of her right foot, rotating her leg medially. Her knee was in semi-flexion at the moment of impact. There was extensive bruising of the outer side of her lower limb, particularly over the outer side of the lower part of the thigh and along the outer border of the foot. The knee showed a postero-lateral dislocation.

A third patient, a university porter aged forty-nine, walked into a hole four feet deep while out for an evening stroll. He could not remember the events in detail, but stated that he severely twisted his left leg with the knee bent. He sustained a postero-lateral dislocation of the left knee.

The remaining two patients, an army despatch rider aged twenty, and a married woman aged forty-one, were injured in road accidents. No detailed history of the mechanism of their injuries was known. Since they were both seated at the time of the accident, one on a motor-cycle and one in a car, with their knees flexed, it is reasonable to assume that the injured limb was not bearing weight when it suffered the violence which produced, in each case, a postero-lateral dislocation of the knee.

Clinical and radiological signs—The clinical signs in the knee were the same in every case. The leg lay in 30 to 40 degrees of medial rotation and some flexion. The medial femoral condyle was prominent and easily palpable under the skin anteriorly. The posterior aspect of the medial tibial condyle was felt protruding into the popliteal fossa. Immediately distal to the bulging femoral condyle the skin was puckered and drawn into a deep transverse groove (Fig. 1). This groove became more pronounced when attempts were made to reduce the dislocation. There was general swelling of the knee in most cases, but no evidence of injury to the nerves or vessels.

The radiographic appearances were also characteristic (Fig. 2). In the lateral view the medial tibial condyle was displaced posteriorly, in consequence of the rotation of the tibia on the femur. Posterior displacement of the lateral condyle was not usually marked. In the antero-posterior view there was some lateral displacement of the lateral condyle of the tibia relative to that of the femur, but never more than a quarter width of the condyle. Because of the medial rotation of the tibia, the medial femoral condyle appeared to project medially to a greater extent. No patient showed a fracture of the tibia or femur.

FIG. 1
Photograph of dislocated knee, showing skin puckering at joint line.

Findings at operation—At operation, as soon as the skin was incised vertically on the medial side of the knee, the medial femoral condyle and its articular cartilage were revealed, bearing the stump of the medial ligament which had ruptured near its upper attachment. The medial ligament, capsule and quadriceps expansion had been torn in the form of an L or an inverted T, and infolded over the medial tibial condyle and medial semilunar cartilage. The free edge of this flap lay in the intercondylar notch. The upper margins of the torn capsule tightly embraced the protruding femoral condyle. Both cruciate ligaments were ruptured. The medial semilunar cartilage was intact in four of the five cases; in the fifth it was loose and was excised.

The medial ligament and capsule were delivered out of the joint, allowing complete reduction of the dislocation, and were sutured. The lateral [external lateral; fibular collateral] ligament was not explored in any case, but the stability of the joint after reduction and suture of the medial structures suggested that it had not been completely torn.

Treatment and prognosis—Four of the five knees in this series were explored within twenty-four hours. In three cases reduction by manipulation was attempted first. The manoeuvre described by Böhler (1935) for irreducible dislocations was unsuccessful, there being an elastic block to reduction, particularly of the lateral displacement. Attempts to correct this caused an increase

of the skin puckering as already described. In one case the nature of the dislocation was not recognised immediately, and the knee was splinted in the " reduced " position. Open reduction was performed several days later.

The period of immobilisation after operation has varied from five weeks to twelve weeks. We consider that six or eight weeks should be long enough to allow sound healing of the torn ligaments and capsule. Emphasis should be placed on muscle rehabilitation from the first day after operation. The knees that have been followed up have been found to be stable except for slight cruciate laxity. A range of flexion to a right angle or beyond has usually been regained.

FIG. 2

Radiographic features. In the antero-posterior view the medial femoral condyle is prominent. In the lateral view the posterior displacement of the tibia on the femur is slight and affects mainly the medial tibial condyle.

DISCUSSION

Although postero-lateral dislocation is rare, it is at least as common as any other type of dislocation of the knee. Among 48,000 bone and joint injuries treated during the last ten years at one of the centres concerned in this report, there were six dislocations of the knee. In two the displacement was posterior, in two anterior, and in two postero-lateral. Smillie (1946) did not mention this postero-lateral dislocation, although he stated that rotary dislocations were known to occur.

Mechanism of injury—The significant points in the history of the injuries recorded here were: 1) the position of flexion of the knee; 2) the fact that the limb was not weight bearing; and 3) the application of a sudden severe force producing abduction and medial rotation of the leg on the thigh. It is suggested that only this combination of circumstances is likely to produce a postero-lateral dislocation with the features described above.

An abduction force of comparable severity in a non-weight-bearing limb with the knee extended, as occurs in the outstretched leg of a footballer when another player falls on it (Smillie 1946), produces a complete rupture of the medial and cruciate ligaments. The joint

is opened out on the medial side, but closes again when the force is released, reducing any temporary subluxation. Only rarely is the medial ligament folded into the joint and trapped there so as to require extraction by operation. When a medial ligament torn in this kind of injury is exposed at operation the general direction of the tear is seen to be transverse. There is no vertical component as in postero-lateral dislocation, and the femoral condyle does not project abnormally.

In postero-lateral dislocation it is the additional movement of medial rotation that produces the vertical tear in the medial capsule and allows the medial femoral condyle to escape from the joint. That this is likely to occur has been demonstrated in cadavers. On strong abduction and medial rotation of the leg, the antero-medial edge of the femoral condyle is thrown into prominence against the taut medial capsule, causing it to rupture in the line of its vertical fibres. The continuation of the abduction and medial rotation movement would then force the femoral condyle out of the joint through the L-shaped or ⅃-shaped tear until the free edge of the tear engages the intercondylar notch, trapping the condyle as through a button-hole, and preventing closed reduction. The corresponding tibial condyle has rotated backwards to lie in a position of postero-lateral dislocation. This last movement is made easier by the flexed position of the knee.

In a weight-bearing knee the same violence, though a less severe one, causes the common tear of the medial semilunar cartilage. It is interesting that in only one of the five cases described here was the medial cartilage damaged.

Importance of early recognition and treatment—Recognition of this injury and of the need for early operation is imperative if good knee function is to be restored. In three of the cases reported here, and in previously reported cases, the diagnosis was made only after manipulative reduction had been recognised as having failed, which, in some instances, was several days later. The clinical and radiological signs are so characteristic and constant that preparation should be made for immediate operation on the assumption that manipulative reduction, which should at least be attempted, will fail. The advantages of early operation, in addition to the relief of pain, are the greater ease of extraction of ligaments that have not become adherent, and their better definition and quality for suture in anatomical alignment.

SUMMARY

1. Five cases of postero-lateral dislocation of the knee with capsular interposition are described.

2. The mechanism of the injury is considered in the light of the case histories and the findings at operation.

3. The constant clinical findings associated with this injury are described.

4. Open reduction is recommended: with early operation the prognosis for function and stability is good.

Our thanks are due to Mr F. W. Holdsworth, Mr R. Weeden Butler, Mr T. J. Fairbank and Professor W. A. Mackey, whose cases are reported.

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FAMILIAL JOINT LAXITY AND RECURRENT DISLOCATION OF THE PATELLA

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Recurrent dislocation of the patella probably has several causes. In many patients abnormal laxity of the knee is present and this may predispose to dislocation (De Palma 1954). A family has come to our notice in which three members suffered recurrent dislocation of the patella and a fourth had probably sustained a single dislocation. All the former had abnormally lax knees and most other joints showed similar hypermobility. Five other living members of the family were also " double jointed " but had not suffered dislocation.

The particular interest of the patients we shall describe lies in the association of familial joint laxity with recurrent dislocation of the patella.

CASE HISTORIES

The pedigree of this family is shown in Figure 1.

The boy, M. S. (IV 3 in the pedigree), who drew attention to the family was six years old when first seen by Mr G. Lloyd-Roberts at the Hospital for Sick Children. He had suffered from recurrent dislocation of the right patella about once a month since the age of four years,

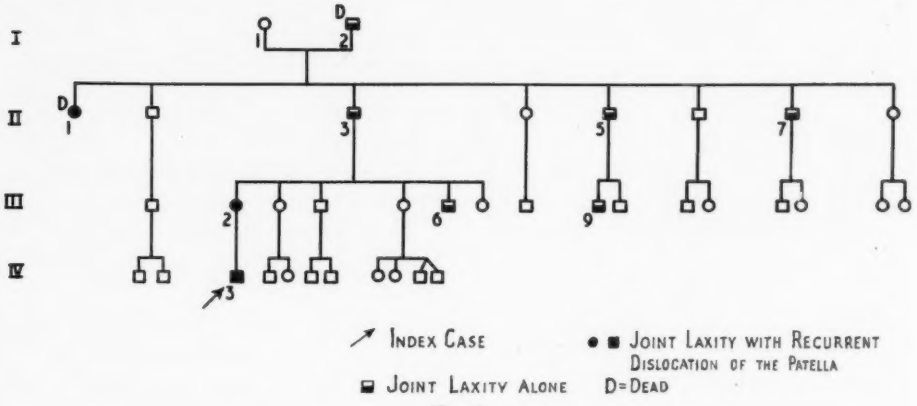

FIG. 1

Pedigree of the family with recurrent dislocation of the patella and joint laxity.

there being no history of injury. On examination the right patella showed abnormal lateral mobility; the medial and lateral ligaments of the knee were abnormally lax and allowed no less than 30 degrees of abduction and 10 degrees of adduction on straining. There was genu recurvatum of 20 degrees. The left knee showed similar, but less marked, instability. There was no fixed knock-knee deformity. Other joints showed an abnormal laxity, most evident in the ankles, wrists and metacarpo-phalangeal joints (Fig. 2) but present also in the shoulders, elbows and interphalangeal joints. Radiographs of the knee showed no abnormality of bone structure.

At operation the medial capsule and patellar retinaculum were markedly atrophic, and this appeared to be the only significant abnormality. To overcome the recurring dislocation the patella was held in place by taking a strip from the quadriceps expansion at the medial side, looping it round the rest of the quadriceps expansion and stitching it to itself; the semitendinosus was also transplanted to the medial border of the patella. The patellar ligament was then split and the lateral half reattached to the tibia medial to its other half. Six months after the operation there had been no further dislocation and an almost full range of movement had been regained.

The mother of the boy, Mrs S. (III 2 in the pedigree), aged twenty-six, had also had recurrent dislocation of both patellae since childhood, which occurred spontaneously about once a month until recently when the frequency diminished. The clinical findings were very like those in her son, the patellae being unduly mobile with a tendency to subluxate laterally

FIG. 2

FIG. 3

Figure 2—An illustration of the remarkable joint laxity in the index case, of the boy M. S., aged six.
Figure 3—Strain radiograph of the mother of the boy in Figure 2 which shows the gross lateral instability of the knee.

on flexion of the knee. She also showed the excessive lateral mobility of the knees (Fig. 3) and genu recurvatum of 15 degrees. Both lateral femoral condyles appeared underdeveloped, and this was confirmed by tangential radiographs of the patello-femoral compartment. She had no other lax joints.

Mr M. (II 3 in the pedigree) was the grandfather of M. S. and the father of Mrs S. Born in 1901, he gave no history of dislocation of the patella, except possibly once on the left, twenty years ago. He, like M. S. and Mrs S., had laxity of both knees. The left knee showed osteoarthritic changes with a small effusion. Radiographic examination was not possible.

Three other living members of the family have a history of weak knees. These are III 6, a brother of Mrs S.; II 5, a brother of Mr M.; and III 9, a son of II 5. On examination, each

of these was found to have genu recurvatum and laxity of the lateral ligaments of both knees. III 9 had bilateral talipes equino-varus. All other living members of the family were examined and one more, II 7, was found to have laxity of the ligaments of both knees. II 5 and III 6 also had significant laxity of the interphalangeal and metacarpo-phalangeal joints. None of these men, however, had had any history of dislocation of the patella. In addition two deceased members of the family, the great-grandfather, I 2, and a great-aunt, II 1, were probably affected. The great-grandfather was said to have " knees which stuck out at the back like ours," and the great-aunt was said to have had the weakest knees in the whole family. " She was a fat woman whose knees gave way every time she laughed." Towards the end of her life she was able to walk only with support, and the account given by the sisters was so characteristic of dislocation of the patella in association with joint laxity that we regard this diagnosis as established.

DISCUSSION

In a study of fifty-four patients with recurrent dislocation of the patella, De Palma (1954) found that " many cases disclosed some lateral instability of the joint arising from generalised relaxation of all the ligaments about the joint." The primary abnormality in the family we report is joint laxity, always affecting the knee, but often other joints as well. Of the six affected members of the family, only one, Mrs S. (III 2), presented any of the other known predisposing causes of dislocation, in this case hypoplasia of the lateral femoral condyles.

The pattern of inheritance in this family is that of a dominant gene, arising as a mutation probably in the great-grandfather (I 2) of our patient M. S. (IV 3). Similar joint laxity with a dominant pattern of inheritance is seen in osteogenesis imperfecta, Marfan's syndrome (arachnodactyly) and Ehlers-Danlos syndrome (McKusick 1956). Patellar dislocation may occasionally occur with these syndromes, but no other signs of any of these conditions are present in this family. Families with joint laxity alone and the pattern of inheritance of a dominant gene have been described by Key (1927) and Sturkie (1941). In Key's family (in which the author is in error in calling the condition sex-linked, since a pair of affected members are father and son) all the joints were affected, and one of the five affected had recurrent patellar dislocation; and it is interesting also that four had talipes equinovarus (like III 9, in our family). In Sturkie's two families there was no dislocation. The family we report belongs to this group of families with joint laxity due to dominant genes.

In spite of the frequency with which lax knee joints are found in association with recurrent dislocation of the patella, this condition is rarely found in more than one member of a family. Further, in addition to joint laxity, there are probably other causes of recurrent dislocation that may on occasion be genetically determined. De Palma (1954) described one patient in his series of fifty-four, a girl whose mother was similarly affected; he did not mention any laxity of the ligaments in this patient. During the past ten years 120 patients with recurrent dislocation of the patella were treated at the Royal National Orthopaedic Hospital; no special family inquiry has yet been made for these, but examination of the notes showed that three (two in the same family) had a relative affected. These three patients were specially examined for joint laxity but none was found. In another girl, whose mother was similarly affected, seen at the Hospital for Sick Children, neither had joint laxity. Lange (1951) has described a Eurasian family with recurrent patellar dislocation; his patients were a girl and her mother, but two sisters of the mother and a sister of the girl were also said to be affected. He made no mention of joint laxity. In the family reported by Moore (1930) the underlying abnormality may have been like that of the family we describe. His patient had recurrent dislocation of both patellae, associated with " a lax joint capsule," and both knees were treated successfully by operation. Nine other members of this family were reported to be similarly affected, but were not examined.

SUMMARY AND CONCLUSIONS

The family we record draws attention to an association between recurrent dislocation of the patella and joint laxity, which is not confined to the knee. This may pass unrecognised if specific inquiry is not made. In this and other families reported, the joint laxity is inherited, as though due to a dominant gene, but some only of those affected suffer recurrent dislocation of the patella. It is probable that there are other genetically determined causes of recurrent patellar dislocation. In three other families we have seen more than one subject of patellar dislocation, but none had lax ligaments, and two other families have been recorded with no mention of associated joint laxity.

We wish to thank Mr G. Lloyd-Roberts for permission to investigate his patient. It is with pleasure that we acknowledge the help given by Dr J. A. Fraser Roberts, Mr H. Jackson Burrows and Mr G. Lloyd-Roberts in the preparation of this paper. We should also like to thank the Photographic Department of the Hospital for Sick Children for the illustrations.

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HALLUX RIGIDUS IN THE ADOLESCENT

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Pain and stiffness in the metatarso-phalangeal joint of the great toe is quite commonly encountered in adolescent patients. In most cases symptoms regress if the joint is protected for a few weeks or months; in the remaining few, however, the symptoms persist and the condition progresses to established hallux rigidus. It is with the latter group of patients that the present work is concerned.

CLINICAL MATERIAL

Nine adolescent patients with hallux rigidus, bilateral in one, which had failed to respond to conservative treatment were seen and treated. In addition, a number of adults who showed features of special interest relating to the etiology of hallux rigidus were studied.

ETIOLOGY

It is probable that a study of hallux rigidus in adolescent patients, particularly those whose disorder persists in spite of conservative treatment, may shed some light on the etiology of established hallux rigidus in adult life and indicate how it may be prevented.

A feature common to all ten affected great toes was limitation of dorsiflexion at the metatarso-phalangeal joint, while at the same time a good range of plantar-flexion was preserved. Attempted passive dorsiflexion of the joint was painful, and it was this painful restriction of dorsiflexion which appeared to be the final common factor for the production of symptoms in all cases.

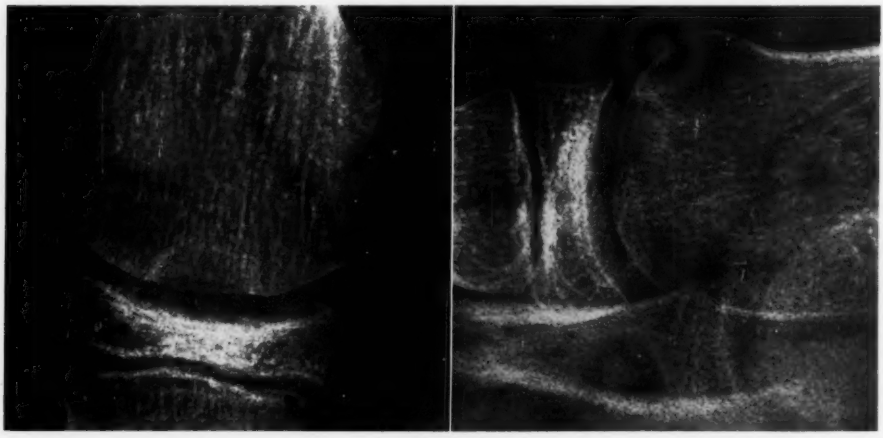

FIG. 1

Radiographs of the metatarso-phalangeal joint of a girl of ten with hallux rigidus, showing the typical lesion of osteochondritis dissecans of the metatarsal head (Case 8).

Although the limitation of dorsiflexion at the metatarso-phalangeal joint has been noted by most workers on this subject (Davies-Colley 1887, Nilsonne 1930, Lambrinudi 1938, Jack 1940) little attention appears to have been paid to the long-continued preservation of a good range of plantar-flexion. As will be seen later, this range of movement can conveniently be used in the treatment of the condition.

In the attempt to determine the cause of the painful restriction of dorsiflexion, we have to consider possible intrinsic disorders of the metatarso-phalangeal joint, extrinsic factors acting on the joint, or a combination of the two.

FIG. 2

Radiograph showing how an osteotomy of the first metatarsal bone for hallux valgus had inadvertently produced an " artificial " metatarsus primus elevatus. The patient subsequently developed hallux rigidus.

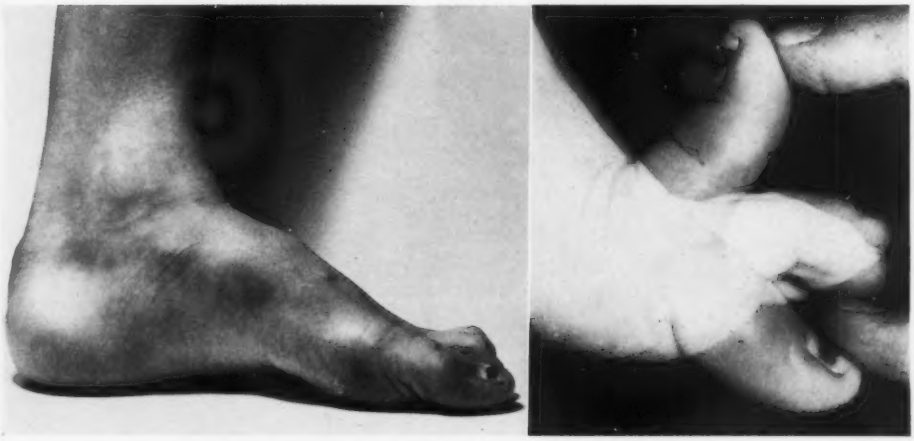

FIG. 3

An adult foot in which depression of the first metatarsal is associated with limitation of plantar-flexion of the metatarso-phalangeal joint, full dorsiflexion being preserved.

In two of our patients there was radiographic evidence of osteochondritis of the head of the first metatarsal (Fig. 1), but we cannot say whether this was a primary or a secondary feature. Our evidence generally, however, is in favour of an extrinsic cause of hallux rigidus and suggests that " hyperextension " of the first metatarsal is the primary cause of hallux rigidus.

The association of hallux rigidus with an established elevation of the first metatarsal has been well known since Lambrinudi (1938) drew attention to it, but there is still some dispute about which is the cause and which the effect. One of our adolescent patients seemed to develop elevation of the first metatarsal *after* the onset of joint symptoms, during the first three months of observation, as if in response to the painful limitation of dorsiflexion at the metatarso-phalangeal joint. Most of the patients, however, showed well marked elevation of the first metatarsal at the time they were first seen, and a study of three adult patients provided further interesting evidence to support the view that in some cases the metatarsal elevation is primary and the joint disorder secondary.

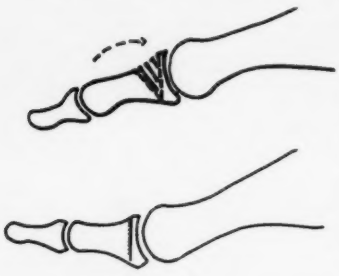

FIG. 4

A wedge of bone based dorsally is removed from the proximal phalanx as close as possible to the epiphysis, the cortex and periosteum of the plantar surface being left intact.

Two adults were seen with an "artificial" metatarsus primus elevatus, the condition having inadvertently been produced by operation: one from an osteotomy of the first metatarsal done for hallux valgus (Fig. 2) and the other after a triple arthrodesis done in the presence of muscle imbalance. The resulting elevation of the first metatarsal in these two patients was followed by the development of typical hallux rigidus—painful restriction of dorsiflexion of the metatarso-phalangeal joint with radiological evidence of degenerative joint changes.

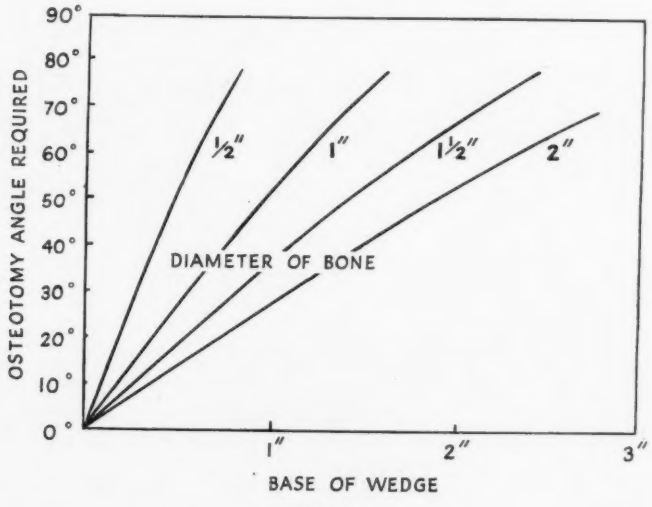

FIG. 5

A graph which can be used to calculate the breadth of wedge required to be removed from bones of varying diameter in order to produce any given angulation.

In a third adult patient an interesting reversal of this condition was noted: marked depression of the first metatarsal was associated with limitation of plantar-flexion of the matatarso-phalangeal joint, full dorsiflexion being preserved (Fig. 3).

This finding is indeed commonly to be observed in those feet showing forefoot equinus or plantaris, when the depressed first metatarsal is associated with limitation of flexion and excessive dorsiflexion at the metatarso-phalangeal joint.

The evidence from the adult cases certainly suggests that any given metatarsal disposition is associated with a corresponding arc of movement of the metatarso-phalangeal joint and that an elevated first metatarsal may determine the limited dorsiflexion of the metatarso-phalangeal joint, which may be followed by hallux rigidus.

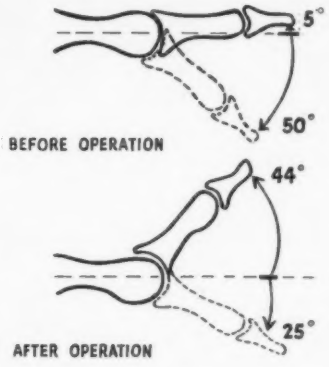

FIG. 6

Diagrammatic representation of the improvement in dorsiflexion obtained by phalangeal osteotomy. (Mean of the result in ten cases.)

TREATMENT

Whatever the sequence of events, the stage may be reached when all conservative treatment, including immobilisation in a below-knee plaster, has failed to relieve the pain, and limitation of dorsiflexion persists. In such cases operation must be considered. The operations applicable in the adult are objectionable in adolescents, and following an earlier suggestion (Bonney and Macnab 1952) we have in these resistant cases performed an extension osteotomy at the base of the proximal phalanx of the great toe in order to transfer the good range of plantar-flexion to a functionally useful range.

Technique of operation—A curved incision about two inches long is centred over the base of the proximal phalanx. The skin flap is dissected up and the phalanx is exposed. A wedge based dorsally is removed from the phalanx as close as possible to the epiphysis, the cortex and periosteum on the plantar surface being left intact (Fig. 4). The breadth of wedge required

FIG. 7

FIG. 8

Case 3—Double exposure photographs to show the improved range of movement and dorsiflexion obtained by operation. Figure 7—Before operation. Figure 8—Two years after operation.

to produce a given angulation can be calculated from a graph (Fig. 5). The phalanx is now angulated to close the gap and the skin is closed. The foot is immobilised in plaster with the great toe forced into extension: there is little danger of over-correction if the size of the wedge has been measured accurately and if the plantar cortex is intact. The plaster is retained for four to six weeks, by which time the osteotomy will be united.

TABLE I

RESULTS OF OPERATION IN TERMS OF PAIN AND FUNCTION

Case number	Age at onset of symptoms (*years*)	Duration of symptoms at time of operation (*months*)	Follow-up period (*months*)	Result	
				Pain	Function
1	12½	18	52	0	good
2	11½	12	45	0	good
3	12½	18	44	0	good
4	9½	17	36	0	good
5	15	12	23	some	fair
6 (R)	14	30	22	0	good
7 (L)	14½	24	20	0	good
8	10	6	18	0	good
9	9	8	16	0	good
10	18	36	5	0	good

TABLE II

RESULTS OF OPERATION IN TERMS OF MOVEMENT

Case number	Range of dorsiflexion and plantar-flexion (*degrees*)	
	Before operation	After operation
1	$<^{0}_{60}$	$<^{45}_{30}$
2	$<^{0}_{70}$	$<^{30}_{35}$
3	$<^{5}_{60}$	$<^{40}_{20}$
4	$<^{5}_{30}$	$<^{40}_{20}$
5	$<^{10}_{75}$	$<^{75}_{20}$
6	$<^{5}_{45}$	$<^{50}_{20}$
7	$<^{5}_{40}$	$<^{60}_{10}$
8	$<^{5}_{45}$	$<^{20}_{40}$
9	$<^{5}_{30}$	$<^{20}_{45}$
10	$<^{10}_{45}$	$<^{60}_{10}$
Mean range	$<^{5}_{50}$	$<^{44}_{25}$

Results of operation—Ten operations have been done on nine patients, whose ages ranged from eleven to twenty-one years. The duration of follow-up ranges from five months to four and a half years. In addition, one such operation has been done on a patient of forty-six with established hallux rigidus. This patient's duration of follow-up is fourteen months. In all but one patient the symptoms have been relieved and painless functional activity has been restored (Table I). A range of dorsiflexion at the metatarso-phalangeal joint of from 20 to 75 degrees has been secured, and in all patients the total range of movement has been increased (Table II, Fig. 7).

In the ten toes operated upon there has been a mean improvement of dorsiflexion from 5 degrees before operation to 44 degrees after operation (Fig. 6). This alteration is clearly demonstrated by double exposure photographs taken before and after operation (Figs. 7 and 8).

COMMENT

The operation is simple, non-destructive and can give satisfactory results; at least for periods of up to four and a half years.

It may be asked whether this operation will prevent the onset of hallux rigidus in adult life. On this point we offer no evidence, but suggest the need for long-term trial to settle the question.

The successful result of operation in the one adult patient, a milk-roundsman who returned to full work ten weeks after operation, raises the question of whether the operation of phalangeal osteotomy has a place in the treatment of established hallux rigidus in the adult. We believe it is worth a trial both when the range of plantar-flexion is preserved and when the joint is fixed in a position of plantar-flexion.

SUMMARY

1. The etiology of hallux rigidus has been studied by an examination of ten adolescent and four adult patients.

2. Although osteochondritis dissecans of the metatarsal head has been seen in two cases, our evidence generally suggests that metatarsus primus elevatus is the important etiological factor in established hallux rigidus.

3. The common factor for the production of symptoms is the limitation of dorsiflexion of the first metatarso-phalangeal joint, just as the key to treatment is the existence of a good range of plantar-flexion of the joint.

4. The technique and results of the operation of phalangeal extension osteotomy for hallux rigidus are given.

We are indebted to Mr S. Jaffe, of the Fulham and Kensington Hospital Group, for the photographs.

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CORRECTION OF THE PRONATED FOOT

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Traditionally, correction of the pronated foot has been achieved by the use of a raising applied to the inner border of the heel or the heel and sole of the shoe, this raising being applied either to the under surface of the sole or, less commonly, to the inside of the shoe. In addition to, or in place of, this method various designs of insoles have been used, or even larger appliances such as an outside iron and an inside T-strap. In considering the relative efficiency of these measures it is important to have some understanding of the mechanics involved, particularly of the peritalar (talo-calcaneo-navicular) joint complex, and also of another joint not previously described, namely the calcaneo-contact articulation.

MECHANICS OF THE FOOT

The simplest type of joint used in everyday life is that of a hinge. The axis of such a joint is clearly the pin running down the centre of the hinge, for it is about the line of this pin that the parts constituting the joint rotate (Fig. 1). If such a hinge is modified, as shown in Figure 2, the axis becomes an imaginary line, and this is a mathematical expression of the shape of the joint surfaces which must be part of the circumference of a circle drawn around the axis—or, more accurately, where there is a single axis to a joint, lines bisecting any chord of the joint surface at right angles in one plane will pass through the same spot. This seemingly pedantic correction is of real importance in considering the function of anatomical joints, for it must be always borne in mind that, no matter how accurately an axis may have been determined experimentally, it will in a particular case depend on the integrity of the joint surfaces, and its ligaments. Provided these conditions are fulfilled its surfaces may be segmented, and special forms of segmental joints of this type can be constructed in which the segments are situated on the opposite sides of the axis (Fig. 3). Furthermore, it should be noted that the radius of each segment need not be the same, provided the one axis is used. A well known example is the articulation of the radius and ulna, where the segments are widely separated, but nevertheless essentially integrated components of a single joint.

No apology is made for the reiteration of first principles, for if these axes are to become the tools of the clinician their uses and limitations must be clearly understood.

The analogy of the hinge can easily be translated into anatomical terms—for example, the interphalangeal joints of a digit. Many joints, the ball-and-socket type in particular, have no such simple axis; but fortunately for the purpose of this paper, as will be seen later, they need not complicate our thinking.

The determination of the axes of the joints of the foot has proved a fascinating source of interest for well over fifty years. Fick (1911), referring to the talo-calcaneo-navicular joint complex, stated that the movement was a simple hinge movement, and that the whole of the subtalar portion of the foot rotated about a line passing obliquely through the head of the talus. Manter (1941), Shephard (1951) and Hicks (1951) have been among the more significant contributors, the work of Hicks being most comprehensive and satisfying so far. He has shown that in the normal foot all movements and changes in the shape of the foot are the result of rotations about axes, and he has determined these axes for each joint. His results correspond closely to those of Manter and Shephard in regard to the axis of what Shephard named the peritalar joint, or the talo-calcaneo-navicular complex. The position of this can

be seen in Figure 4, and Shephard showed that the axis of the talo-navicular joint, as determined from the joint surfaces, also corresponds to the axis of the subtalar joint.

It is a property of hinge joints that they are what Steindler has called " trackbound ": that is to say the plane of movement of a joint is always perpendicular to its axis, and different

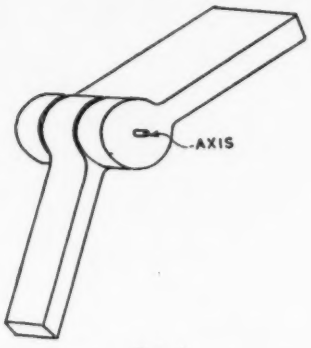

FIG. 1

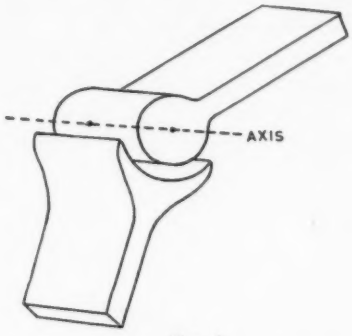

FIG. 2

Figure 1—Solid axis of a hinge. Figure 2—Modification of the joint to conform to an anatomical hinge joint. The axis now becomes a mathematical expression of the curvature of the joint surfaces.

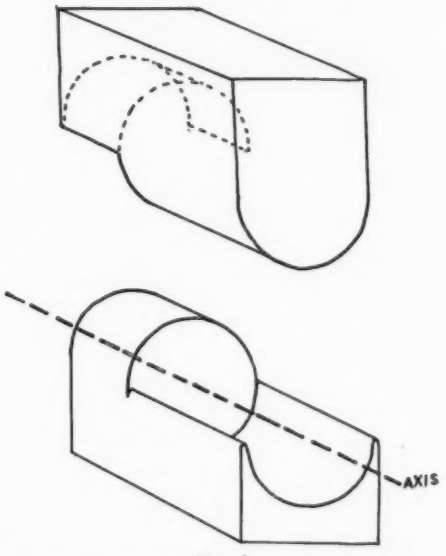

FIG. 3

A modified anatomical hinge joint with segmented articulations on the opposite sides of a single axis. This joint corresponds closely to the subtalar joint.

forces applied to this joint, although they may run in oblique direction, always produce one of two movements, a clockwise or anti-clockwise rotation about the axis—quite unlike the movement produced at a ball-and-socket joint, which will always be in the plane of the resultant of forces acting upon the joint. In the hinge joint the efficiency of the movement compared with the force will be most marked when the force is at right angles to the axis,

diminishing to nil when it lies in the line of the axis. Physiology must not be forgotten in considering this mechanical situation, and it is clear that the trackbound quality of joints has to be maintained by a certain balance of muscles acting about a joint. Consider for example the function of the saddle-shaped trapezio-metacarpal joint. It is a common experience that when muscle transplants are performed to produce opposition of the thumb in a paralysed hand they are usually successful at first, but fail as the trackbound quality of the joint becomes lost under the repeated stress of a tension pulling in a single plane; then the thumb, instead of performing a movement closely resembling normal opposition, merely adducts across the palm.

That the movement of all joints in the foot—and in particular the movement of the peritalar joint complex—is a pure rotation, has been disputed by many observers who have noticed a gliding movement in the mid-tarsal region, and this they have attributed to a glide occurring at the subtalar joint. In fact, however, it is produced at the calcaneo-contact

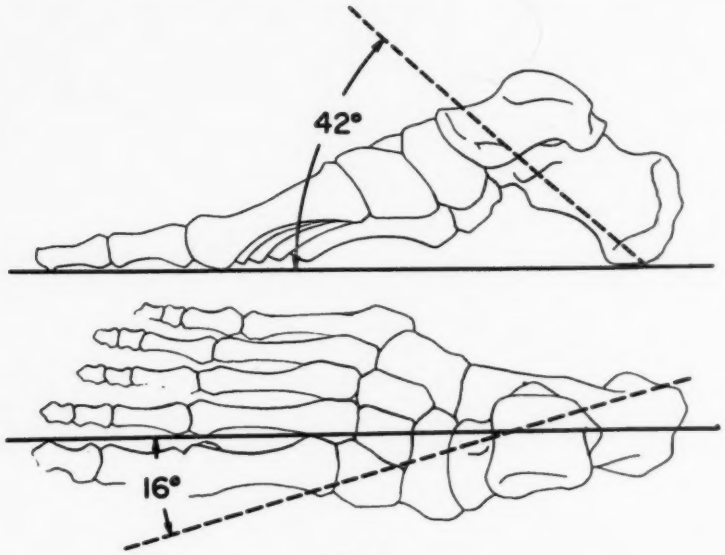

FIG. 4
To show the axis of the subtalar joint. (From Manter 1941.)

articulation. It has long been recognised that the movements of the foot appear different in the standing foot from those that are observed when the foot is held above the ground, and it will be seen that this difference is the product of a particular movement occurring at the calcaneo-contact surface and the rotation at the peritalar axis.

The weight-bearing surface of the calcaneum is dome-shaped. In the antero-posterior plane, part of this dome has an important function in the heel-and-toe action of normal walking; but when the foot is used as a static weight-supporting structure it is the transverse contact area of this dome which becomes important, and when the foot is fully weight bearing a modified type of trackbound articulation is formed between the calcaneum and the ground, or, more accurately, in part between the skin beneath the calcaneum and the ground, and in part between the calcaneum and the fibro-fatty pad between it and the skin. This articulation differs from the joints of the foot in that it is not a simple hinge joint, but has the same mechanism as does that of a wheel moving over the ground, the axis itself moving in space parallel to the ground as rotation occurs around it. In other words the surfaces do not slide

one over the other, lacking the lubrication and frictional qualities of articular cartilage, but roll one on the other with a high degree of friction between them (Fig. 5).

Since for practical purposes the axis of the subtalar joint may be considered to be embedded in the calcaneum, it will be seen that this causes a movement in space of the subtalar axis about which rotation of the talus can occur relative to the calcaneum (Fig. 7).

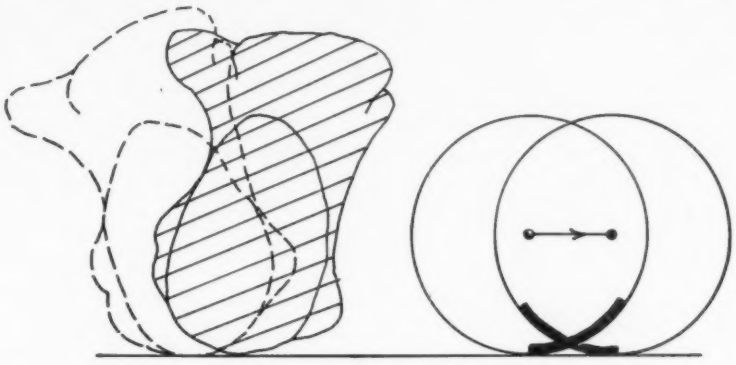

FIG. 5
Calcaneo-contact articulation showing the wheel-like movement.

Furthermore, in the standing subject with the knees straight any movements of the talus which occur are, again for practical purposes, linked through a solid rod comprising the tibia and the femur to the hip joint, which in the conditions laid down will allow rotation only about a vertical axis.

In order to translate this into visual terms a model was constructed of acrylic, the subtalar joint being represented by two plain surfaces separated by a metal spacer, the axis of the

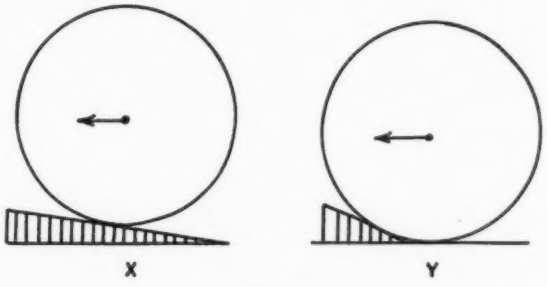

FIG. 6
To demonstrate the efficiency of a wedge placed medial to the calcaneum as opposed to that of a generalised raise of the inside of the heel in preventing inward roll. Y is much more effective than X.

joint being embedded in the calcaneum and running freely through the talus. The tibia and femur were represented by a single bar embedded into the upper surface of the talus, and this allowed to rotate in a loose ring at the top of the stand (Figs. 8 to 10). From this model certain important practical points immediately became obvious. 1) The wheel effect of the calcaneo-contact joint is shown (Figs. 8 and 9). 2) This is accompanied by a shift in the

peritalar axis embedded in the calcaneum which, interreacting with the rotation possible in the bar representing the locked tibia and femur, produces a movement of the head of the talus which is in the almost horizontal plane, trackbound through the rotation of the tibia and the roll of the calcaneum at the calcaneo-contact articulation. The trackbound quality of this linkage is emphasised by the fact that only movement of the head of the talus in a clockwise or anti-clockwise direction relative to the tibial axis can be produced, no matter in what direction force is applied to the linkage. Conversely, as the foot pronates, the head of the talus moves inwards and exerts the greatest force in a horizontal plane against the lateral wall of the peritalar joint.

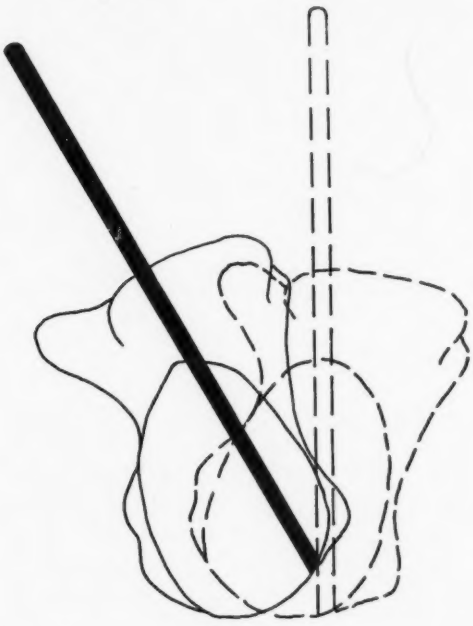

FIG. 7
The glide in space of the axis of a peritalar joint with movement of the calcaneo-contact joint.

On this model it is quite clear that pressure from below the talus and vertically upwards achieves nothing, except a tendency to lift the whole foot upwards, whereas the most efficient correction of the in-turned talar head is relatively easily achieved when a horizontal force is applied from the inner border of the foot outwards in the coronal plane against the head of the talus itself. This clearly demonstrates the futility of the internal longitudinal arch support as a corrective device and relegates it to its proper position as a simple support of osteoarthritic joints. Because of the trackbound effect already noted this correction can also be brought about by twisting the calcaneum or the tibia; but clinically these methods are much less practical. These points were fully appreciated by Whitman when he designed his plates, and this principle of correction was advocated later by Charlesworth and more recently by Helfet, who has produced a more modern and effective version of the Whitman insole.

Elevation of the inner border of the shoe acts in two ways. 1) By tilting the calcaneum. Its effectiveness in this direction is limited by the fact that the raise of the medial border both lifts and tilts the calcaneum, so that the amount of correction that can be produced is

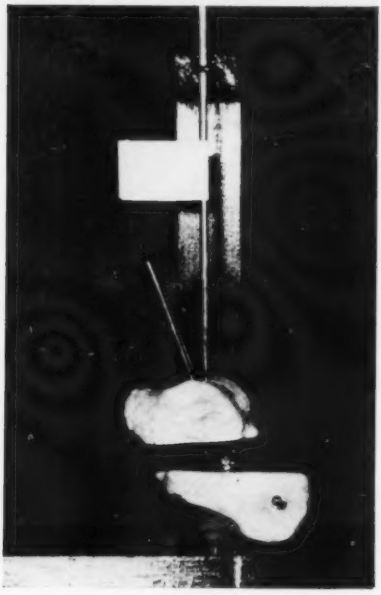

FIG. 8

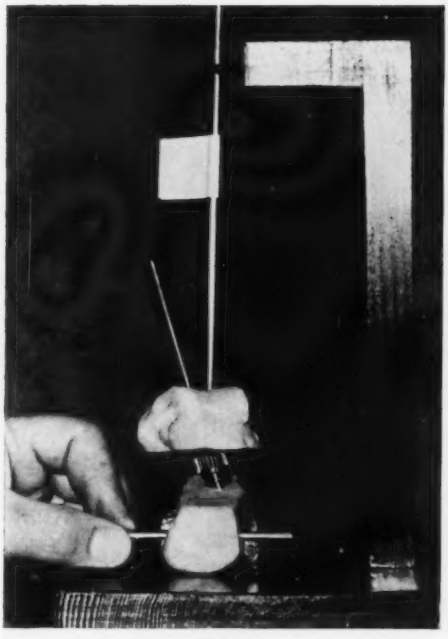

FIG. 9

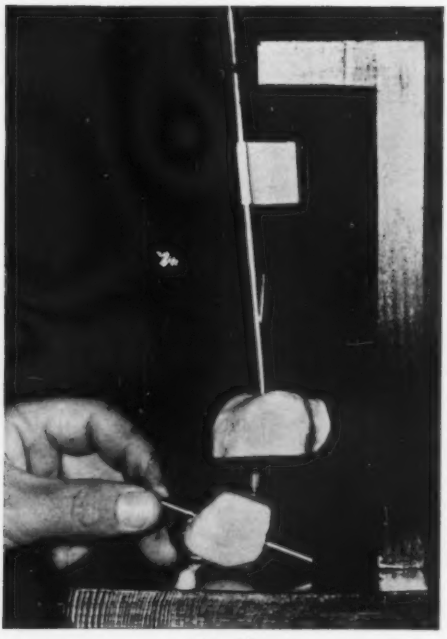

FIG. 10

An acrylic model to demonstrate the trackbound relationship between the tibia, the peritalar joint axis and the calcaneo-contact joint in the standing weight-bearing foot.

ultimately limited by the angle of slope of the heel. If this becomes too great, it causes the foot to slide laterally and lie in an uncorrected position, between the angle of the heel and the outer wall of the upper. This correction is effective whether the raise is applied to the outside of the shoe or to the inside. The degree of correction provided by this method alone

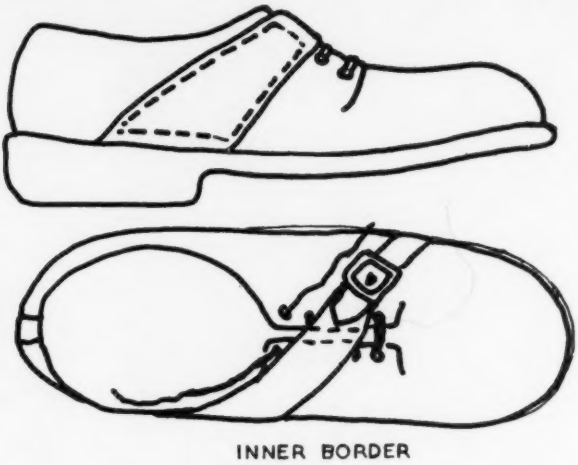

FIG. 11

Valgus strap to reinforce the pressure over the inner side of the talar head. The dotted lines in the upper figure indicate a stiffening inserted into the strap.

is relatively small. Schwartz has pointed out that a wedge inserted inside the shoe will have a different effect from a generalised raise of the inside of the heel, and can be used to prevent inward rolling of the calcaneum at the calcaneo-contact articulation. It has the disadvantage that the degree of correction is not easy to control (Fig. 6). 2) By the pressure of the inner border of the shoe in an outward direction on the region of the head of the talus. This is in turn limited by the rigidity of the upper of the shoe in the region of pressure, and it is common to see that this rigidity is inadequate and the leather is deformed here. In practice this is probably the most effective action of a medial raise, and it occurs much less efficiently when the raise is placed inside the shoe rather than on the outer surface of the heel. When a correction of only a modest degree is required, this method of treatment may be reinforced by the addition of a valgus strap (Fig. 11). In more severe cases the type of heel cups described by Helfet (1956) are extremely good. They provide a means of transmitting the vertical body weight into a horizontal force (Fig. 12). Their effectiveness depends upon: 1) the manufacture of the insoles with the foot fully corrected; and 2) the manufacture of the insoles with materials that will neither deform nor crack under the considerable force applied.

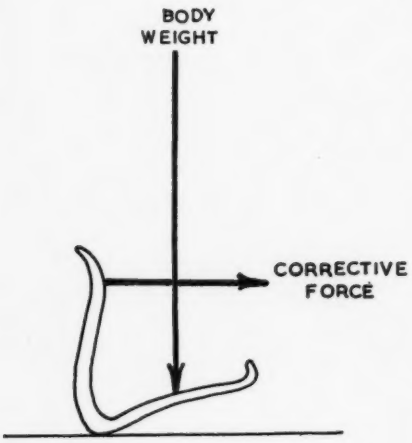

FIG. 12

Illustrates the transformation of the vertical force of body weight into a corrective horizontal force by means of the heel cup. This is a section through the cup.

CONSTRUCTION OF INSOLES

Taking the pattern—A cast of the foot is made either in putty or preferably with a plaster slab, the foot weight bearing, the correction being achieved by full dorsiflexion of the great toe, assisted, if necessary, by lateral rotation of the tibia. Many instrument makers seem to

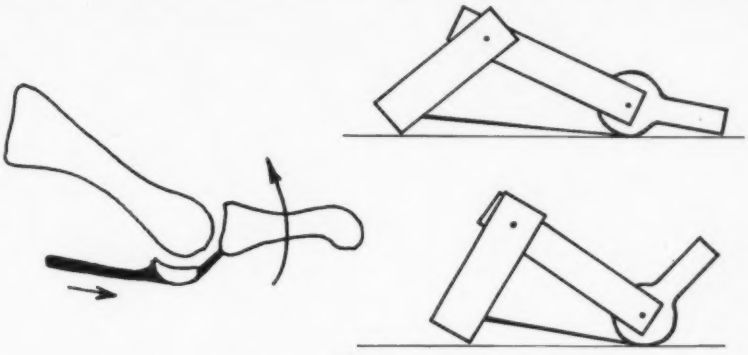

FIG. 13

Illustrates (*left*) the anterior attachment of the plantar aponeurosis to the proximal phalanx of the great toe through the sesamoids and (*right*) the windlass effect on extending the great toe. (After Hicks, 1951.)

be reluctant to make an insole from a weight-bearing case which, with its flattened heel surface, has a marked difference in appearance from the traditional insole. Nevertheless if pressure areas on the inner side of the foot are to be avoided it is essential that the insole be made to fit the weight-bearing foot.

FIG. 14

FIG. 15

Photographs illustrating the rise in the medial longitudinal arch and the roll of the calcaneum that accompany extension of the great toe owing to the windlass effect of the plantar aponeurosis.

Correction of the foot deformity by dorsiflexing the great toe was described by Jack (1953), and the mechanism by which it is achieved was elucidated by Hicks (1951). Hicks showed that the plantar aponeurosis, attached behind to the calcaneum and in front in the case of

the great toe to the base of the proximal phalanx through the sesamoid bones, acts as the rope of a windlass, the metatarsal head being the drum and the proximal phalanx the handle. Raising the great toe increases the tension in the fascia and also causes a shortening relative to the internal longitudinal arch of the foot. In consequence the calcaneum is rolled outwards with the effects that have already been made clear from the model, and the first metatarsal ray is flexed, which in the standing foot also elevates the arch (Figs. 13 to 15). This is an important observation which can be put to practical use in the taking of impressions from the foot.

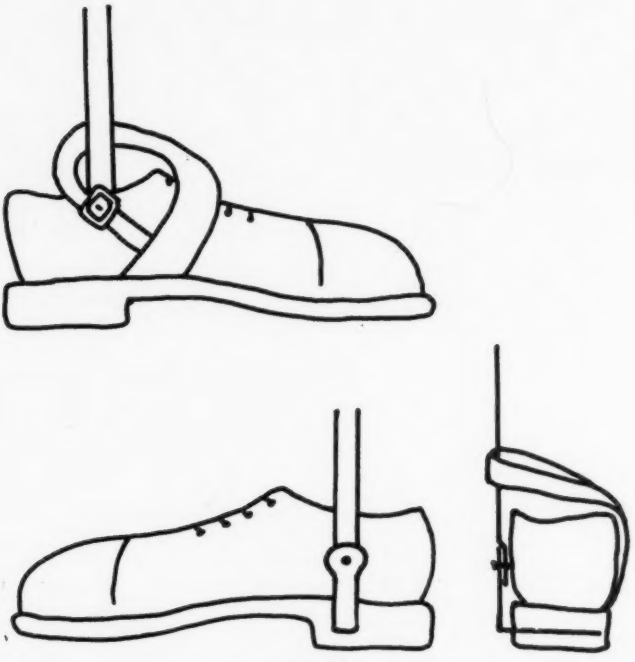

FIG. 16

Special modification of the outside iron and inside T-strap. It will be noted that the T-strap is modified to bring the maximum pressure over the talar head, and as this instrument is used in small children very frequently, it has been found that the ordinary socket into the heel is technically difficult and heavy, so that a light simple hinge has been used, as indicated.

Materials used—Durability of the arch supports is best achieved by manufacture with laminations of ordinary surgical bandage impregnated with a cellulose cement, reinforced with what in the boot trade is called " bottom filler," which is powdered cork impregnated in the cellulose cement (Charlesworth 1951). In prolonged use these have proved extremely satisfactory. Block-leather heel cups easily go out of shape under the influence of sweating, and fibre-glass or other plastics tend to crack.

COMMENTS

These heel cups cannot be used for small children, in whom the most efficient type of corrective device is the outside iron with an inside T-strap. Special care should be taken over the design of the T-strap in order that the entire force of this strap should be a horizontal transverse force on the head of the talus. Figure 16 shows the important difference between the traditional strap and the one which is recommended.

No special consideration has been given here to the difference in effectiveness between an inside raise of the heel only, often prolonged forward for strength, and an inside raise of the sole and heel. This question cannot be considered from a theoretical point of view without bringing in further considerations regarding the mechanics of the forefoot and the interrelation between these and the hind foot which have not been dealt with in this paper. Nevertheless it is clear from the arguments adduced here that an inside raise of the sole and heel of the shoe will tend to produce a better horizontal corrective force against the talus head than a raise only of the heel, and this in my opinion is sufficient to make this prescription universal. There are further good reasons to support this view from considerations of the mechanics of the foot as a whole, and these will be dealt with later.

SUMMARY

1. The mechanical qualities of the peritalar joint, the calcaneo-contact joint, and their interreaction with the hip joint in the standing weight-bearing foot are considered.
2. The most efficient ways of correcting the pronated foot have been indicated.

I am indebted to the Research Committee of the Birmingham Regional Hospital Board for a grant which made this work possible.

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TROCHANTERIC FRACTURES OF THE FEMUR TREATED BY THE VITALLIUM McLAUGHLIN NAIL AND PLATE

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From the Bradford Accident Service

This paper is based on a study of 142 fractures of the trochanteric region in 141 patients (one bilateral case). My aim is to present these cases in some detail and to compare the results with those obtained with other types of nail-plate. The stresses occurring in nail-plates have been analysed, and the results of laboratory tests on various nail-plates will be presented.

Advantages of adjustable nail-plates—The McLaughlin nail-plate is easy to insert, causing minimal damage to the lateral femoral cortex. It can be fitted accurately to the fracture without fixation under stress. A large stock of nail-plates in varying lengths and angles is unnecessary, and cold-bending of the nail-plate is avoided: this practice is undesirable, for minute nicks and scratches inevitably caused represent potential points of failure (" notch effect "), and the disturbance of the crystalline structure of the metal may, in the case of steels, cause electrolysis (Wright and Axon 1956).

CLINICAL MATERIAL AND ROUTINE OF TREATMENT

From 1952 onwards all patients admitted to the Bradford Accident and Orthopaedic Service with trochanteric fractures were assessed by the surgeon and anaesthetist with a view to internal fixation with a McLaughlin nail-plate.

Evans (1951) pointed out that the type of hospital may affect the type of patient referred: this factor does not apply to the present series because all fractures occurring in the area (population about 450,000) are dealt with by the Accident Service.

The operation was usually carried out at the next (twice weekly) operation session, but when necessary a few days were spent in pre-operative medical treatment, usually with benefit. The average time between admission and operation was 6·4 days.

The number of cases in which operation was withheld is too small to be worthy of analysis. It includes a few patients virtually moribund on admission. Subtrochanteric fractures and those with reversed obliquity (Evans's Type II) were usually treated conservatively, or, if with much displacement, by intramedullary nailing. If the pre-operative period exceeded twenty-four hours Russell traction was applied. Considerable comminution was no bar to operation provided the site for the plate was not extensively shattered.

Types of fracture—The classification suggested by Evans (1949) was employed. The incidence of the different types of fracture is shown in Table I.

The proportion of unstable fractures is higher than in other reported series, in keeping with the high average age.

All deaths occurring before discharge from the unit are included. The mortality of 9 per cent (Table II) slightly exceeds that of Evans (1951), who quoted 8 per cent for operative treatment in his own series, but is better than the 16·8 per cent calculated by him from a survey of eight other reports. Kennedy, McFarlane and McLachlin (1957) had a mortality of 18·8 per cent with the Moe plate. The causes of death are shown in Table III. The main cause of death only is given in each case; multiple contributory factors were usually present.

TECHNIQUE OF OPERATION

The nail was inserted through a lateral incision under radiographic control in two planes. Guide wires ten inches long and three-thirty-seconds inch in diameter were used. The aim was

to place the nail just below the centre of the femoral neck with the tip half an inch short of the joint. A nail-plate angle of 140 degrees was aimed at, the average angle achieved being 137 degrees. In the present series the original pattern Vitallium McLaughlin nail-plate with quarter-inch set-screw was used.

TABLE I

TYPES OF FRACTURE

Type			Per cent
Type I	Stable	Undisplaced	17
		Stable after reduction	34
	Unstable		48
Type II			Nil
Subtrochanteric			1

TABLE II

AGE DISTRIBUTION AND MORTALITY

Age (*years*)	31–40	41–50	51–60	61–70	71–80	81–90	91+	Total	Per cent	Average age
Number of patients	4	2	5	37	51	40	3	142	—	74·0
Hospital deaths	—	—	—	1	5	7	—	13	9	81·4

TABLE III

POST-OPERATIVE COMPLICATIONS AND CAUSES OF HOSPITAL DEATHS

Complication	Number of cases	Principal causes of hospital deaths	Number of deaths
Pneumonia	8	Pulmonary embolism	2
Pulmonary embolism	4	Pneumonia	3
Pressure sores: heel	3	Pressure sore and wound infection	3
sacrum	7	Cardiac failure	3
Phlebitis	7	Coronary thrombosis	1
Wound infection	6	Uraemia and suppurative parotitis	1
Urinary	8		

TECHNICAL COMPLICATIONS

Nail—The nail bent slightly in one case in a man of forty-seven who persisted in early weight bearing against advice. There was a final varus deformity of 15 degrees, but function was excellent.

Plate—Failure of the plate was not encountered.

Screws—A few screws broke during insertion, but none broke or cut out subsequently.

Nail-plate junction (Table IV)—Disruption occurred in twelve cases. The set-screw broke in three (2 per cent) and came completely undone in nine (6 per cent). Though this is unsatisfactory, McLaughlin (1955) reported an incidence of 32 per cent failures with this pattern. Despite his condemnation, the makers state that considerable numbers are still being used.

On follow-up the set-screw was found to be partly unscrewed in three cases. One patient achieved an excellent result, and the other two have good function but 20 degrees of varus.

Figures 1 to 6 illustrate the various types of failure.

TABLE IV

FAILURES OF NAIL-PLATE JUNCTION

Case number	Age	Type of fracture	Cause of failure	Time after operation	Result
24	69	Stable. (Severe osteoarthritis of hip)	Set-screw broke	4 weeks	Died; wound infection and pressure sores
88	32	Undisplaced	Set-screw broke	During operation	New set-screw inserted; untraced
125	80	Unstable. (Severe osteoarthritis of hip)	Set-screw broke	2 weeks	New set-screw inserted; good result
38	67	Subtrochanteric. (Hip arthrodesed)	Set-screw undone	7 weeks	Good result
58	71	Unstable	Set-screw undone	13 weeks	Good function; 30 degrees' varus
61	72	Subtrochanteric. (Severe osteoarthritis of hip)	Set-screw undone	2 weeks	New set-screw inserted; untraced
63	85	Stable	Set-screw undone	5 weeks	Function fair; died at 25 months
82	77	Unstable	Set-screw undone. Late wound infection	1 year	Nail-plate removed; fair function
87	62	Unstable	Set-screw undone	13 weeks	Good function; 45 degrees' varus
98	32	Unstable	Set-screw undone	12 weeks	Good function; 30 degrees' varus
122	80	Stable	Set-screw undone	12 weeks	New set-screw inserted; good result
128	72	Stable	Set-screw undone	6 months	Fair function; no varus

Removal of nail-plate—The nail-plate was removed in seventeen cases, for the following reasons: penetration of joint space, eleven; wound infection, two; breakage of set-screw, one; loosening of set-screw, one; cutting-out of nail (pathological fracture), one; pain in hip, one.

LATE RESULTS

Thirteen patients died in hospital, and eighteen have died since discharge without adequate follow-up. Five are untraced. There thus remain 106 patients for assessment (Table V). Four gradings, functional and anatomical, were used, which correspond as far as possible with those used by Kennedy *et al.* (1957) and by Murray and Frew (1949).

Functional grading—*Grade* 1*: poor*—Bedridden or confined to chair. *Grade* 2*: fair*—Requires stick, considerable limp or pain. *Grade* 3*: good*—Walks well, uses stick to go out. Only slight limp or pain. *Grade* 4*: excellent*—Walks as well as before operation. No limp or pain.

Anatomical grading—*Grade* 1*: poor*—Severe malunion. Varus deformity of 25 degrees or more, or over an inch of shortening. *Grade* 2*: fair*—Union with 10–25 degrees of varus, and half an inch to one inch of shortening. *Grade* 3*: good*—Union with less than 10 degrees of varus and minimal shortening. *Grade* 4*: excellent*—Union in perfect position.

TABLE V

FINAL ASSESSMENTS IN 106 CASES. (MINIMUM FOLLOW-UP SIX MONTHS)
(Percentages)

	Functional grading					Anatomical grading				
Grade	Undisplaced	Displaced: stable	Unstable	Subtrochanteric	Total	Undisplaced	Displaced: stable	Unstable	Subtrochanteric	Total
1	1	—	2	—	3	—	—	2	—	2
2	4	6·5	7·5	1	19	1	2	8	1	12
3	3	22	15	—	40	1	5	14	1	21
4	8	12	17	1	38	12	30	23	—	65
Average functional grading 3·1						Average anatomical grading 3·5				
Average stay in hospital 28 days										

The average functional grading was slightly better than that reported by Kennedy *et al.* (1957) with the Moe plate (3·1 against 2·9); the anatomical grading was also better (3·5 against 3·1), largely because the incidence of varus deformity was only 11 per cent compared with 25 per cent with the Capener-Neufeld nail-plate (Evans 1951) and "about half the cases" with the Moe plate, which appears to resist varus deformity badly.

Non-union did not occur except in the case of pathological fracture through a metastasis. Avascular necrosis did not occur, nor was marked limitation of knee movements (not pre-existing) discovered.

DISCUSSION

If Grades 3 and 4 are regarded as satisfactory the proportion of satisfactory results compares well with other series (Table VI).

TABLE VI

COMPARISON OF SATISFACTORY RESULTS IN FOUR SERIES OF CASES

Author	Satisfactory functional grading	Satisfactory anatomical grading
Present series	78%	86%
Kennedy *et al.* (Moe plate) .	69%	71%
Evans (1951). (Capener type) .	68%	74%
Murray and Frew. (Conservative)	67%	62%

The incidence of disruption of the nail-plate junction (8 per cent) is too high; when the new Model V McLaughlin device (McLaughlin and Garcia 1955) (Fig. 7) became available in 1957 it was decided to change to this. About two years must elapse before an adequate series can be assessed, but meanwhile the modifications in design were subjected to critical

FIG. 1

FIG. 2

Case 24—Man aged sixty-nine. Unstable fracture; osteoarthritic hip. Figure 1—First post-operative film. Figure 2—Set-screw broke at three weeks while patient was turning over in bed. Died four months after operation.

FIG. 3

FIG. 4

Case 38—Woman aged sixty-seven. Cup arthroplasty 1949. Arthrodesis of hip 1951. Figure 3—Fracture through site of insertion of arthrodesis nail two years later. Nail-plate fixation was undertaken, but after seven weeks the set-screw was found to be undone. Figure 4—Final radiograph showing the fracture consolidated. The result was satisfactory, with excellent function.

FIG. 5

FIG. 6

Case 98—Woman aged thirty-two. Nail-plate fixation of trochanteric fracture. Figure 5—First post-operative radiograph. Figure 6—At three months the set-screw was found to have come undone. The fracture is united, with 30 degrees of varus. The functional result was good.

scrutiny. They are: 1) A four-finned nail instead of trifin, claimed to give 25 per cent greater strength. 2) Cutting point on nail. This appears to minimise splitting of the cortex at the site of insertion. 3) Strengthened plate. This has always been well designed, with tapering flanges giving maximum strength where most needed, at the shoulder. 4) Replacement of the quarter-inch set-screw by a five-sixteenths-inch stud on the base of the nail. Since the strength of such a stud is proportional to the cube of the diameter, this gives a theoretical strengthening of 125 : 64, or almost double. Although (unlike the set-screw) the stud is cannulated, its strength is not reduced so much as might be thought because, when subjected to bending stress, the upper part of the stud is in tension, the lower in compression. There is thus a central zone where these stress systems meet and cancel out. The locking collar is held in place by a three-thread nut with a nylon locking washer in a circular groove behind the thread—a device found helpful in the aircraft industry. McLaughlin and Garcia (1955) reported fifty cases with the new device: no nut had come undone.

FIG. 7
New Model V McLaughlin nail-plate.

The weak point of all nail-plates so far described has been the angle between nail and plate. The force applied to the nail at and near its tip exerts a bending moment which is maximal at this point.

STUDIES OF STRENGTH IN NAIL-PLATES OF DIFFERENT PATTERNS

The strength of various types of nail-plate was calculated in terms of the bending moment causing breakage or gross permanent deformation (Table VII). The method of calculation is shown in Figure 8.

TABLE VII

STATIC LOADING TESTS

Test number	Type of nail-plate	Metal	Bending moment causing failure (*lb.–inches*)
1	Moore	SMo stainless steel	217
2	Jewett	SMo stainless steel	217
3	Thornton	SMo stainless steel	351
4	Pugh	SMo stainless steel	408
5	Neufeld	SMo stainless steel	361
6	Neufeld	Vitallium	402
7	Capener	SMo stainless steel	391
8	McKee	SMo stainless steel	83
9	McLaughlin (old type)	Vitallium	322
10	McLaughlin (new type)	Vitallium	448

The figures for tests 1–6 in Table VII were calculated from Martz's (1956) paper and from additional information kindly supplied by Dr Martz. The last four tests were carried out on an Avery Hydraulic Load Tester: the plate was screwed to the vertical face of a steel cube and the force applied vertically to the nail tip, as in Figure 8 (block and screws omitted for clarity).

In tests 7 and 8 the nail-plates bent at the angle and in test 9 the quarter-inch set-screws broke, at the average values shown. The tests on the new McLaughlin nail-plate confirmed the makers' claims that the five-sixteenths-inch stud could not be broken, the nails bending at the average value shown. This table is not intended to compare one metal with another, but to show that the new type McLaughlin nail-plate is substantially stronger than the old and compares favourably with a representative selection of nail-plates.

In the body, circumstances are rather more favourable than in the experimental conditions depicted in Figure 8. 1) The force on the femoral head is transmitted not only to the tip of the nail, but to that part embedded in the proximal fragment, thus reducing the effective leverage on the nail-plate angle. 2) The resultant of the forces acting on the femoral head is not vertical, but inclines 10–15 degrees medial to the perpendicular (Inman 1947). 3) The plate is not vertical, being screwed to the femoral shaft, which inclines downwards and medially at an angle of 9–15 degrees to the vertical (Walmsley 1933).

These factors are illustrated in Figure 9. They have the same effect on the stresses at the nail-plate angle as if that angle were increased by the sum of angles in (2) and (3) above. In Figure 9 these angles have been given minimal values of 10 degrees each.

In studies of the function of the hip abductors Inman (1947) calculated the force on the femoral head at about two and a half times the body weight when weight is taken on the limb. This force is the resultant of the body weight and the balancing downward pull of the hip abductors on the lateral side of the pelvis.

For a given effective nail length and load the bending moment at the nail-plate angle varies as:

Cosine (nail-plate angle—90 degrees).

This is shown graphically in Figure 10. From 140 degrees upwards the curve falls steeply (7 per cent per 5 degrees): hence the advantage of placing the nail as vertically as possible.

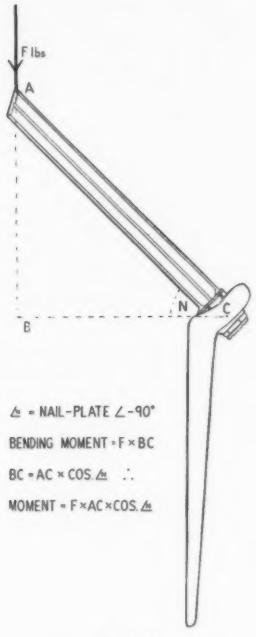

FIG. 8

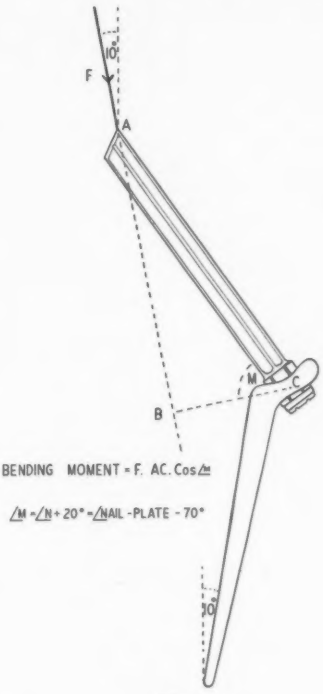

FIG. 9

Figure 8—Forces acting on nail-plate under test conditions and method of calculating bending moment at nail-plate junction. Figure 9—Forces acting on nail-plate as placed in the body, and method of calculating bending moment at nail-plate junction.

Although early weight bearing was advised in only the more stable fractures in this series, the advantages of operation are not fully realised unless the patient is sitting out of bed in a chair within forty-eight hours and getting about on crutches as soon as possible. Inadvertent weight bearing is always possible, and if the medial cortical buttress is shattered little support is given by the bone, and the angulating force will be considerable. For example, if the patient's weight is 150 lb., length of nail 4½ inches (less half an inch on account of factor (1) above), the moment at the nail-plate angle will be 634 lb./inches if the nail-plate angle is 135 degrees, or 513 lb./inches for 140 degrees.

The new McLaughlin device will probably withstand at least 600 lb./inches at the nail-plate junction. It remains to be seen whether the nail will bend more often now that the weakness at the angle has been eliminated.

All nails, plates and screws used in this series were of Vitallium. Titanium is a possible alternative, but as its modulus of elasticity is about half that of Vitallium, bending of the nail would probably be more frequent.

Effect of stiffness of the hip—If the hip is stiff or arthrodesed the leverage exerted by forces applied at the foot will be very large. If the effective lever is thirty-four inches long a force of only 20 lb. exerts a moment of 680 lb./inches. Abduction or adduction stresses will tend to break the stud, and flexion and extension of the right and left hip respectively will exert powerful rotational stresses tending to undo the nut. In this series one hip had been arthrodesed for osteoarthritis (Figs. 3 and 4), and nine showed gross osteoarthritic changes with stiffness. Disruption of the nail-plate occurred in no less than five of these ten cases.

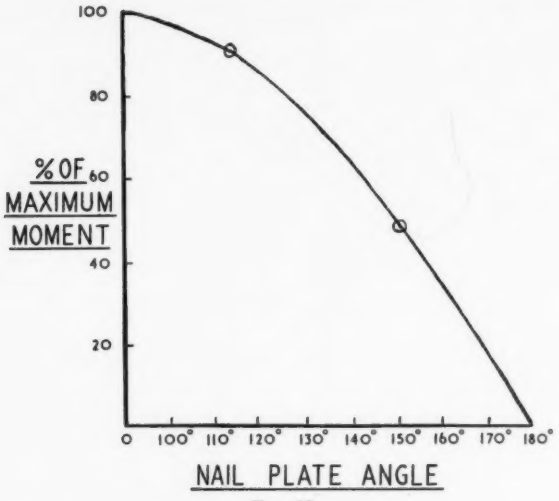

FIG. 10
Bending moment plotted against nail-plate angle. Marked points indicate range of McLaughlin adjustable nail-plate.

Metal fatigue—The fatigue curve for Vitallium shows that after repeated application of a force of about one-third of the ultimate breaking force the strength of the component falls quite rapidly. The curve shows that after 10,000 stresses the strength is about 40 per cent of the original value. The curve then flattens out, there being little further loss of strength after 1,000,000 stresses.

Fortunately, with trochanteric fractures union is usually sound before fatigue seriously weakens the nail-plate.

Over-stressing during insertion may predispose to subsequent breakage. One set-screw broke during insertion. The makers state that a torque of 160 lb./inches should not be exceeded during tightening of the quarter-inch set-screw, which can easily be done with the usual T-wrench. This is not likely to be a problem with the new pattern.

SUMMARY AND CONCLUSIONS

1. A series of 142 fractures of the trochanteric region treated by fixation with Vitallium nail-plates of the original McLaughlin pattern is described. The hospital mortality was 9 per cent. Disruption of the nail-plate junction occurred in 8 per cent of cases. This confirms McLaughlin and Garcia's (1955) view that this pattern of nail-plate should no longer be used.
2. Despite this, satisfactory functional results were achieved in 78 per cent of the survivors.
3. The new Model V McLaughlin nail-plate is described, and the stresses in nail-plates are considered. On theoretical grounds and laboratory tests the weakness at the nail-plate junction has been eliminated in the new model, and the strength of the appliance as a whole compares

favourably with other types of nail-plate. Full clinical trial is therefore justified, and seventy-one patients have so far been operated on, with satisfactory early results.

4. Marked stiffness of the hip joint greatly increases angulatory and rotational stresses on the nail-plate, and a high incidence of disruption is to be expected in these cases.

My thanks are due to Mr A. Naylor and Mr J. Wishart, under whose care these patients were treated, for their encouragement. I would also like to thank Mr R. W. Beatty, of the English Electric Company, for metallurgical advice and for carrying out laboratory tests on various nail-plates. The London Splint Company and Austenal Inc. of New York have also provided valuable information.

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TREATMENT OF PERTROCHANTERIC AND BASAL FRACTURES OF THE FEMUR BY IMMEDIATE FIXATION WITH A TWO-PIECE NAIL AND PLATE

A Review of 100 Consecutive Cases

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One hundred consecutive pertrochanteric and basal fractures of the femur treated by immediate internal fixation with a McKee nail and plate have been studied. The patients were treated at the Middlesex Hospital or the King Edward Memorial Hospital, Ealing, between January 1952 and May 1956. During this period all but five patients with such fractures were subjected to operation. There were sixty-six women averaging seventy-six years of age and thirty-four men averaging seventy-one. Nineteen were transferred from a local geriatric unit and formed an adversely selected sub-group. The remainder were admitted directly from their homes.

Classification of fractures—Fractures were classified into pertrochanteric and basal, with further subdivision into " stable " and " unstable " according to the stability of the medial cortex after reduction and fixation of the fracture (Evans 1949, 1951). In the stable fracture there is accurate contact of the medial cortex, without comminution or fracture-separation of the lesser trochanter or compression deformity of the back of the neck and shaft. Further subdivision appeared to have no practical value for the purposes of this review. Subtrochanteric fractures were not included, although some of the comminuted pertrochanteric fractures had a subtrochanteric element. There were six basal fractures and ninety-four pertrochanteric fractures: 60 per cent were classified as stable and 40 per cent as unstable.

Associated disorders—Many pre-existing conditions, ranging from stiff joints caused by old tuberculosis to peptic ulceration with haematemesis, were encountered. Cardiac lesions, generalised arterial degeneration and senile mental deterioration were common, often proving the governing factor in post-operative rehabilitation. Six patients suffered upper limb fractures at the time of the accident, but none gave rise to any particular difficulty in management. There were no other associated injuries of consequence.

ROUTINE MANAGEMENT

All patients were operated upon within six hours of admission. Operation was carried out under general anaesthesia, and a blood transfusion averaging two pints was given. The patients were lifted out of bed into a chair at the earliest opportunity after operation, usually on the first day. Assisted hip and knee movements were begun at once. Walking with crutches, without weight bearing when the fracture was unstable, was encouraged as soon as the wound was healed and post-operative discomfort had settled. It was considered that a well nailed stable fracture might bear weight at once, whereas in the unstable fracture some evidence of union should be awaited. General frailty or concomitant disease often caused delay in this programme.

RESULTS

Preservation of life—The total mortality within four months of operation was 9 per cent (Table I). The mortality among those admitted in the normal way (eighty-one patients)

was 5 per cent; the mortality in those admitted from a geriatric centre (nineteen patients) was 26 per cent. The cause of death was determined by necropsy in every case but one; the findings are summarised in Table II.

TABLE I

MORTALITY (100 CASES)

Source	Total number of cases	Number of deaths	Mortality
Middlesex Hospital			
Transfers from geriatric unit	19	5	26%
Direct admissions . .	43	4	5%
King Edward Memorial Hospital	38	0	
Whole series	100	9	9% (Men 17·6%, Women 4·2%)
Average age at death—83·6 years			

TABLE II

CAUSES OF DEATH

(Confirmed by post-mortem examination in every case except Case 45)

Case number	Age	Sex	Time after operation	Cause of death
2	79	Male	4 days	Coronary occlusion
10	80	Male	12 weeks	Confluent bronchopneumonia (sacral bed-sore)
25	87	Female	14 days	Coronary occlusion
37	86	Male	6 days	Coronary occlusion
45	87	Male	23 days	Coronary occlusion (clinical diagnosis)
88	89	Female	20 days	Coronary occlusion
89	94	Female	2 days	Peripheral circulatory failure with pulmonary oedema and collapse
97	79	Female	12 weeks (first operation) 5 weeks (re-operation)	Bronchopneumonia
98	75	Male	1 day	Hypertensive heart failure

Union and functional recovery—The patients from the geriatric department are included in the mortality statistics to give an unbiased picture, but since they passed from our direct care soon after operation (average time sixteen days) the following analysis concerns only the seventy-seven surviving patients who were admitted from their homes. Seventy-four were followed at least until the time of union of the fracture and return to normal walking. Information concerning the remaining three is incomplete, but they were known to have survived and to have walked without crutches.

Union of the fracture—Every fracture in this series united, the average time until radiological union being eleven weeks.

Varus deformity—The average loss of shaft-neck angle between time of fixation and bone union was less than 5 degrees. In eleven the loss was greater than 10 degrees, the greatest being 20 degrees. All but one of those fractures were classified as unstable, but weight bearing had been allowed at an average time of six weeks from operation—usually on account of difficulty in managing crutches—which was two weeks earlier than the general average time for allowing weight bearing on unstable fractures.

Technical failures—In no instance did the McKee nail or plate break or bend, nor did the screws lose their grip. The technical failures that occurred in eight patients are summarised in Table III. One unusual fracture, leading to technical failure of nail-plating, was encountered in a woman aged sixty (Fig. 1). The action of the ilio-psoas muscle caused rotation of the

TABLE III

ANALYSIS OF TECHNICAL FAULTS (EIGHT CASES)

Nature of fault	Number of cases	Presumed cause	Further treatment	Effect on outcome
Intrusion of nail across joint	6	Nail too long at insertion (3 cases)	Nail removed after union (Cases 53 and 72)	None
			Renailing with shorter nail at 7 weeks (Case 56)	Weight bearing delayed until 10 weeks. Ultimately satisfactory
		Poor reduction, with later collapse (3 cases)	Attempted renailing at 6 weeks unsuccessful owing to x-ray failure. Internal fixation abandoned in favour of traction (Case 3)	Very slow union: 5 months before weight bearing. Ultimately satisfactory
			Removal of nail and plate at 12 weeks. Immobilisation in plaster spica (Case 87)	Union at 19 weeks. Ultimately satisfactory
			Re-operation at 7 weeks (Case 97)	Died 5 weeks later from bronchopneumonia
Slackening of bolt	1	Failure to tighten adequately	Bolt tightened at second operation at 10 days	None
Skin pressure from prominence of bolt (after union of fracture)	1	Extreme thinness of patient	Removal of nail and plate	None

upper fragment, which made reduction impossible in the ordinary supine position on a traction table. The nature of the problem was not appreciated at operation and consequently the fracture was fixed in poor position; collapse and intrusion of the nail necessitated a second operation for removal of the nail three months later, when the fracture had not yet united. A further seven weeks of immobilisation in a plaster spica was necessary. Rehabilitation was slow, but six months later the patient was walking well and had returned to her work as an office cleaner. Reduction by a direct grip on the proximal fragment or possibly division of the offending spike would have prevented this failure. Three of the fractures with a transverse subtrochanteric element and medial displacement of the shaft (the " reversed obliquity " group of Evans 1951) were intentionally fixed in this position on the analogy of a McMurray osteotomy (Fig. 2). The results were less satisfactory than in those anatomically reduced, and the one death possibly attributable to technical failure occurred in this group (Case 97). Intrusion of the nail due to lack of stability necessitated re-operation at seven weeks, and the patient died five weeks later from bronchopneumonia.

FIG. 1
Case 87—Marked rotation of the upper fragment.

Walking—All surviving patients, with the exception of one woman who was virtually bedridden before the fracture on account of neoplastic disease, eventually walked. The average time before weight bearing was four weeks for stable fractures and eight weeks for unstable. We have no figures for time of attainment of completely unaided walking because progress was usually gradual; patients were encouraged to use a stick permanently when walking out of doors and many continued to do so.

Residual pain in the hip was not common and seldom complained of spontaneously, nor was stiffness of the knee a problem in any case. So many factors having nothing to do with the fracture or its management enter the picture in the elderly that a detailed assessment of the final function of the hip would serve no useful purpose.

Complications—There was no significant wound sepsis in this series. A few post-operative haematomata required evacuation, but none gave rise to complication. There was no case of fatal pulmonary embolus, but a few patients suffered minor thrombotic episodes. Troublesome chest infections were remarkable by their absence. Only one patient developed a serious bed-sore; in this case the normal programme of post-operative treatment was impossible on

FIG. 2
Fixation with medial displacement of the shaft fragment.

account of senile mental deterioration, general weakness and incontinence (Table II, Case 10).

Length of stay in hospital—This is shown in Table IV. The discrepancy between the central city hospital (Middlesex) and the suburban hospital (Ealing) reflects social and not surgical differences and is further discussed later.

TABLE IV

AVERAGE LENGTH OF STAY IN HOSPITAL

Hospital	Number of patients	Length of stay
Middlesex Hospital . . .	39	5·4 weeks } Average 7·4 weeks
King Edward Memorial Hospital	38	9·2 weeks }
Geriatric Unit Transfers . .	14	16 days (transferred)

DISCUSSION

Pertrochanteric and basal fractures of the femur are among the commonest causes of admission of the elderly to orthopaedic wards. In this series there were nearly twice as many women as men, but men sustained the fracture at an earlier age and suffered a mortality four times greater.

Five patients admitted during the period under review were treated conservatively: two refused operation and three were judged unfit for an anaesthetic. One of the latter patients, a severe diabetic, died, but the others survived the period of conservative treatment and returned to walking. We might doubt in retrospect if assessment of unfitness for anaesthesia was correct, but in any case the number is too small to be significant.

The advantages and disadvantages of operative and conservative management have been argued at length by many authors (Cleveland, Bosworth and Thompson 1947; Murray and Frew 1949; Evans 1949, 1951; Scott 1951; Clawson 1957). Comparison of the main statistics of this series with those of a similar series of patients treated conservatively (Murray and Frew 1949) is shown in Table V. The striking difference is that in the present operative series the time in hospital was halved although the average age of the patients was considerably higher.

TABLE V

COMPARISON OF CONSERVATIVE AND OPERATIVE TREATMENT

Source	Number of patients	Average age	Mortality	Average bed occupancy
Murray and Frew . . (Conservative treatment)	100	62·5 years	10%	14·5 weeks
Present series . . . (Internal fixation)	100	75 years	9% (5% for "normal" admissions)	7·4 weeks

This is a salient point, not only because of the ever present shortage of beds, but because of the social difficulties involved in getting many of these old people back to their previous surroundings—a very real problem that may increase markedly with a prolonged stay in hospital. In the extreme case one old lady remained in hospital for seven months because it

was impossible to find anywhere for her to go. These social difficulties explain the difference in time of hospital stay (Table IV) between the two hospitals concerned in this review, a very active almoning department more effectively overcoming the problem in the city hospital.

Skilled nursing may overcome the hazards of prolonged immobilisation of the elderly, but the virtual abolition of the classical dangers of pneumonia and bed-sores in the present series testifies to the greater ease of nursing a mobile and unencumbered patient. Late function is probably adequate in most surviving patients whether treated conservatively or by operation, although the danger of a stiff knee is much reduced by internal fixation, provided early mobility is encouraged. We therefore agree with Murray and Frew that the ultimate governing factor in deciding between the two alternative forms of treatment must be the mortality rate. Comparison of the causes of death in the two series is of interest. In their series, in accord with the generally accepted pattern, respiratory complications accounted for seven deaths, pulmonary embolism for two and cerebral haemorrhage for one. Nine of these deaths can be considered directly related to the fracture or the immobilisation necessary in its treatment. In our series only two patients died from respiratory complications, both in the twelfth week after operation and still bed-ridden because of failure of operation in its purpose (Case 10 and Case 97, Table II). Two deaths occurring on the first day after operation, one from peripheral circulatory failure and the other from hypertensive heart failure, must be attributed directly to the intervention. The relationship to operation of the remaining five deaths, all due to cardiac infarction from coronary occlusion and occurring between the fourth and twenty-third day after operation, is much more difficult to decide. This is a common enough cause of death at this age even in the absence of injury and operation, but the proportion is large to be a chance finding, and no case of death from coronary occlusion appears in the conservatively treated series. It might be that the enforced rest of conservative management would have given these patients a better chance of survival; but none had a gross cardiac lesion demonstrable before operation and selection would seem nigh impossible.

Every fracture in the present series united. Boyd and Lipinski (1957) reported non-union in between 1 and 2 per cent of a large number of patients treated by internal fixation at the Campbell Clinic. They made the observation that non-union is commoner in the younger patients. This would constitute a further small point in favour of internal fixation in the elderly. Fractures of the nail or plate generally occur in the presence of non-union or delayed union, which is the primary failure (Taylor, Neufeld and Nickel 1955; Boyd and Lipinski 1957). This mishap did not occur in our series, but the incidence of other technical failures resembled that reported by Taylor, Neufeld and Nickel (1955) who used a one-piece fixation device (Table III). By no means all the nail-plate fixations that ultimately gave satisfactory results conformed to the highest standards of technical perfection, and the impression was of the remarkably wide margin of error compatible with a good result. Indeed, in these fractures, we may speak of the "good results of bad nail-plating." We did not find the marked difference in results of stable and unstable fractures reported by Clawson (1957), who suggested that the results of nail-plate fixation in the unstable group are so unsatisfactory that members of this group should be treated conservatively.

CONCLUSION

The routine use of early internal fixation by means of the two-piece device of McKee in the management of pertrochanteric and basal fractures of the femur has given highly satisfactory results. These results, particularly in saving life, are largely due to modern improvements in anaesthesia and resuscitation, which have greatly reduced the hazards of operation in the elderly. The advantages of early internal fixation, when adequate technical facilities are available, are such that it is the method of choice in all patients, particularly the elderly. The question must not be "is the patient fit for operation?" but "is he fit to leave without operation?".

SUMMARY

1. The results of treatment of 100 consecutive patients with pertrochanteric and basal fractures of the femur treated by early operative fixation with a McKee two-piece nail and plate are reviewed.
2. Technical failures are analysed and discussed.
3. The pattern of mortality is discussed and contrasted with that in a comparable series of patients treated conservatively.
4. It is concluded that early operative fixation is the method of choice in the management of these fractures, and that the McKee pin and plate is a satisfactory and reliable device for securing internal fixation.

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THE ETIOLOGY OF HYPEROSTOSIS CRANII (METABOLIC CRANIOPATHY)

A Clinical Study

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Hyperostosis cranii or metabolic craniopathy was first recognised as an essential part of Morgagni's syndrome of virilism, obesity and hyperostosis frontalis. It is a syndrome of uncertain origin which was believed to occur almost exclusively in middle aged and elderly women. More recently it has been shown to occur in younger women and rarely to occur in men.

The syndrome is characterised by thickening of the inner table of the skull, more usually in the frontal region, but it may also occur over other parts of the skull, including the basal bones and the orbital plate. There may be generalised thickening of the whole calvarium. In the frontal region especially, the inner surface of the skull may become nodular and it may attain a depth of more than a centimetre. This thickening consists of spongy bone containing large numbers of osteoblasts and the underlying dura is usually thickened and adherent.

NOMENCLATURE

Hyperostosis cranii has usually been referred to as hyperostosis frontalis interna, which is a part of the Morgagni syndrome. The Stewart-Morel syndrome is the name introduced by Schiff and Trelles (1932) for that group of cases in which changes in the mental state are found in association with obesity, virilism and hyperostosis frontalis interna. It later came to be recognised that the skull changes occur apart from obesity and virilism and that they may involve areas of the skull other than the frontal bones. This led to the introduction of the name metabolic craniopathy by Moore (1936*a*). In his recent monograph on the subject, Moore (1955) used the title hyperostosis cranii, which name will be used throughout this paper.

TYPES OF HYPEROSTOSIS CRANII

In a study of 6,650 skull radiographs over a period of twenty-four years Moore (1936*b*) identified four types of thickening of the calvarium, which he named hyperostosis frontalis interna, nebula frontalis, hyperostosis calvariae diffusa, and hyperostosis fronto-parietalis (Figs. 1 to 3).

Hyperostosis frontalis interna—This is the most characteristic type and involves the frontal bones, with deposits of bone on the inner tables.

Nebula frontalis—In this the change in the calvarium consists of a triangular or ellipsoid area of increased density located in the frontal region and extending downwards from a base on the sagittal plane.

Hyperostosis calvariae diffusa—In this third type there is generalised thickening of the calvarium with an increase of density of the diplöe. The basal bones also may be involved.

Hyperostosis fronto-parietalis—In this form, which is probably a stage in the development of hyperostosis calvariae diffusa, there is thickening of the inner tables of the frontal and the parietal bones.

It is generally accepted that these four types are expressions of the same entity. Hence the name hyperostosis cranii may be used to cover all four.

Moore (1936*b*) found the incidence of these types of hyperostosis in 6,650 skull films as follows: hyperostosis frontalis interna 1·44 per cent; nebula frontalis 1·14 per cent; hyperostosis

FIG. 1
Nebula frontalis or early hyperostosis frontalis interna.

FIG. 2
Hyperostosis calvariae diffusa.

calvariae diffusa 0·6 per cent; hyperostosis fronto-parietalis 0·3 per cent. The total incidence of hyperostosis was 3·5 per cent in 6,650 skulls.

In an examination of 582 skulls in a department of anatomy, Moore (1936*b*) found forty-six with hyperostosis cranii (hyperostosis frontalis interna, twenty-nine cases; nebula frontalis, fourteen cases; hyperostosis calvariae diffusa, three cases).

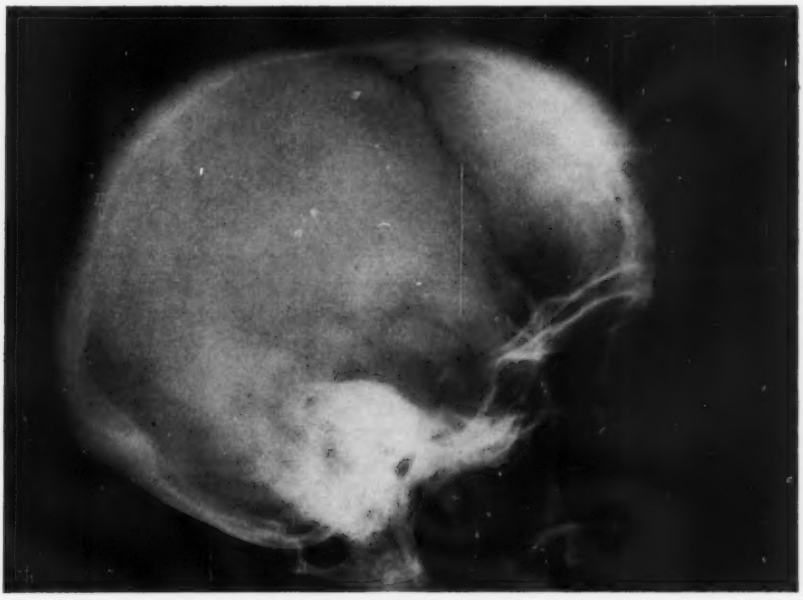

FIG. 3
Hyperostosis fronto-parietalis.

AGE AND SEX DISTRIBUTION

It can be said that the incidence of hyperostosis cranii among the general population is unknown. On the other hand, most workers who have studied this syndrome have noted the overwhelming occurrence among women. Henschen (1949) found that 99 per cent of his cases were in women, and Moore (1935) 98·2 per cent. The only exception to this was a small group of fifteen patients with dystrophia myotonica and hyperostosis cranii reported by Caughey (1952*a*), in which the distribution was ten males to five females.

The most common age at which the syndrome occurs is in the fourth, fifth and sixth decades. Recent studies by Moore (1955) of a large group of healthy young women revealed that 14 per cent had some slight degree of hyperostosis cranii.

SYNDROMES ASSOCIATED WITH HYPEROSTOSIS CRANII

Hyperostosis cranii accompanies several clinical states.

Morgagni's syndrome—In his original report, Morgagni (1765) described the necropsy of an obese, virile, hirsute woman, with an overgrowth of bone in the inner aspect of the frontal bones, and Henschen (1936) coined the term Morgagni's syndrome for cases with this triad.

Stewart-Morel syndrome (Morgagni-Morel syndrome)—Shattock (1913) described thickening of the calvarium in the insane, and Stewart (1928) wrote on the same topic. Morel (1930) first diagnosed a case before death. Schiff and Trelles (1932) introduced the title of Stewart-Morel syndrome, and Calame (1951) used the name Morgagni-Morel syndrome to designate

those examples of the Morgagni syndrome with associated disturbances in the mental state.

Hyperostosis cranii with acromegaly—A general thickening of the calvarium and other evidence of hyperostosis cranii have long been recognised in patients with acromegaly. It is noteworthy too that marked degrees of hyperostosis cranii in acromegaly are most usually seen in women. In Moore's (1955) study of forty-eight patients with acromegaly and acromegaloid cases, nine had hyperostosis cranii and of these eight were women.

Troell (1938) and Junet (1938) first reported cases of acromegaly with thyrotoxicosis. In all, eleven cases of this type have been described. All were in acromegalic women, ten of whom had enlarged nodular thyroids. Seven had diabetes and all but one had metabolic craniopathy with thickening of the calvarium. Three had hyperostosis frontalis interna.

Dystrophia myotonica and hyperostosis cranii—This received mention by Rouquès (1931) and Fagin (1946). Caughey and Brown (1950) discussed this aspect of the disorder and suggested that the skull changes occurred so often that they should come to be recognised as one of the variable features of the disorder. Later, Caughey (1952*a* and 1952*b*) reported fifteen cases of dystrophia myotonica with skull changes, and with a preponderance in men as stated above.

Senile hyperostosis cranii—In Moore's (1955) valuable statistical study, the highest incidence of hyperostosis cranii was in the fifth and sixth decades; there remained a considerable group in the seventh and eighth decades which on occasions have been called the senile group of hyperostosis cranii.

ETIOLOGICAL CONCEPTS

Various concepts of the disease have been proposed and relevant studies have been reviewed by Knies and Le Fever (1941). Syphilis has been suggested by Marchand and Bauer (1925). Bonnamour and Jamin (1926) and Picard (1926) suggested that it was an aberrant form of Paget's disease. Caughey, Gwynne and Jefferson (1957) recently reported a family with familial Paget's disease and dystrophia myotonica which was considered to be coincidental. Knaggs (1925) supported the suggestion of an inflammatory background. Injury as a mechanical cause of congestion has been invoked but has been dismissed for lack of evidence. Morel (1930) considered that the syndrome was the result of generalised calcium dysmetabolism and suggested that the frontal region might be conditioned by the tension of adherent dura. Naito and Schüller (1923) and Dressler (1927) suggested that the bony changes of metabolic craniopathy might be compensatory to senile changes in the brain with atrophy and subsequent thickening of the inner tables.

A possible relationship to puerperal osteophytes has been suggested by various authors. Greig (1928) considered that if a mother does not nurse her baby there is an excess of calcium circulating in the blood which might favour its deposition in certain areas. Against these suggestions, Moore (1936*b*) showed that 50 per cent of women with hyperostosis cranii have never been pregnant. Carr (1936) noted an abnormality of menstrual function in 76·4 per cent of a rather small series. The possibility of a relationship to the menopause has been postulated by many but recently considered unlikely in view of the occurrence in young women.

More recent studies focus attention on the endocrine system. Moore stated: " In general terms the syndrome is the expression of an uncontrolled growth stimulus common to both sexes. Because the process of reproduction is more dynamic in the female than the male the former are more subject to the condition. There is no evidence of general influence on all tissues comparable with acromegaly."

PURPOSE OF THIS STUDY

Moore (1955) stated that the cause of hyperostosis cranii resides in both sexes. In previous studies of the syndrome, as seen in dystrophia myotonica, it is apparent from a small but convincing series of cases that hyperostosis cranii is one of the variable and common features of the disorder and that it occurs in males and females alike. In other series of cases of

hyperostosis cranii of all types quoted by Henschen (1949) and by Moore (1955), there has been an overwhelming preponderance of female cases. Thus it seems possible that the key to the problem may be found in a study of dystrophia myotonica.

The case material is drawn from a personal group of fifty cases of dystrophia myotonica with the fully developed disorder. A series of reports has already been published dealing with the cataract, the endocrine features of the disease, the bone changes in the skull, unilateral elevation of the diaphragm, congenital physical defects, and cardiac changes; and recently the family with familial Paget's disease and dystrophia myotonica has been reported.

In this present publication the endocrine changes and the hyperostosis cranii will be reviewed and an attempt will be made to discover etiological factors that could account for the hyperostosis cranii.

DYSTROPHIA MYOTONICA

Dystrophia myotonica is a heredo-familial disorder which is transmitted by male and female alike and by both normal and affected individuals. When the mutation first makes its appearance in a family, cataract is the usual presenting feature. In subsequent generations the cataract usually occurs at an earlier age and is associated with the other features of the fully developed disorder such as muscle wasting, myotonia, loss of reflexes and certain endocrinological changes of which the most constant are gonadal atrophy, frontal baldness and hyperostosis cranii. The sex distribution of the disease is reported by most workers to be equal among males and females.

ENDOCRINE CHANGES IN DYSTROPHIA MYOTONICA

Early studies of the ductless glands by Wilson (1940) showed changes that were " too banal for any conclusions to be drawn." Adie and Greenfield (1923) described changes in the pituitary body and in the cortex of the suprarenal glands which " were beyond what is usual." Other endocrine glands were not described.

In an endocrine study of nine cases Caughey and Brown (1950) made an attempt to assess the endocrine changes (Appendix 1). The main conclusions were as follows.

Body growth—The skeletal proportions of these patients were within normal limits, the height and span being approximately equal, and the vertex-to-pubis measurements equal to the pubis-to-sole measurement. There was no radiological evidence of delay of epiphysial closure. These clinical observations, the previous history of the patients, and the endocrine studies which will be discussed later left little doubt that the hypogonadism was a post-puberal type.

Hair growth—Frontal recession of head hair is well recognised in the disorder and in the series was apparent in all the male cases. Changes in body hair were variable. Two men showed scanty growth of facial hair. In four men the secondary sex hair was normal in amount and distribution.

General function—In all the patients in the series the onset of hypogonadism occurred some time after puberty, as was evident from the normal skeletal proportions, the normal development of secondary sex hair, the size of the genitalia, the normal voice, and the normal radiological appearance of the long bones and sinuses. Hypogonadism always begins some time after the onset of myotonia and wasting. One woman had noticed difficulty in relaxing her grip twelve years before, but had since given birth to three children. In the men the size of the penis was normal and the scrotum was well developed; the distribution of pubic hair was normal except in two, in whom it was of female distribution. The testes in five were soft, and the size of a small almond; in two they were normal. Normal testicular sensation was present. Potentia was much reduced, but still present, and occasional emissions occurred. The prostate was examined in four, and was small in each case. Examination of the semen of one patient failed to reveal active spermatozoa. Testicular biopsy was carried out in three patients in an advanced stage of the disease, and the following observations were made.

Case 1: Atrophy both of seminiferous and of interstitial elements was almost complete in both testes. The basement membranes of the seminiferous tubules persisted, but no spermatogenic or supporting cells were to be seen. A few vestigial Leydig cells were present. *Case* 8: In the specimen examined the seminiferous tubules had for the most part atrophied completely, the zones normally occupied by epithelial cells being filled by hyaline fibrous tissue. One or two tubules still contained spermatocytes with pyknotic nuclei, but there was no evidence of spermatogenesis. Interstitial cells were identified with difficulty and appeared degenerate. *Case* 9: Two pale grey portions of tissue of irregular contour were examined and found to consist of epididymal tubules and ducti efferentes. No spermatozoa were found in their lumina.

Gynaecomastia—Gynaecomastia was noted in one male patient only (Case 1), and followed treatment with testosterone, by injection and implant, for twelve months. The development of gynaecomastia in a proportion of eunuchoid males treated with testosterone was reported by McCullagh and Rossmiller (1941). Klinefelter, Reifenstein and Albright (1942) pointed out that the production of this kind of gynaecomastia depends on the presence of androgen and the absence of spermatogenesis, conditions which were both present in this patient. Two other male patients were treated with testosterone but did not develop gynaecomastia.

Follicle-stimulating hormone—The assay was made by the Klinefelter, Albright and Griswold (1943) method, using the enlargement of the immature mouse uterus as the end-point. A result was considered positive when the mouse uterus weighed 10 milligrams or more. Normal excretions by this method lie between 13 and 54 mouse units in twenty-four hours. Assays of the follicle-stimulating hormone were carried out on five of the patients, four male and one female. Three of the male patients (Cases 1, 8 and 9) had the fully developed syndrome with gonadal atrophy, and their urine excreted in twenty-four hours was positive to 96 and negative to 192 mouse units. The excretion in the patient in Case 7, who was past the menopause and who would normally be expected to have a high hormone value, was strongly positive to 96 mouse units. The patient in Case 3, who had no loss of libido or sexual power, and whose testicles and prostate gland appeared normal, excreted normal amounts of the hormone (positive to 26 mouse units in twenty-four hours, and negative to 54). In general, these results agree with those of Benda and Bixby (1947), who found in one of their patients an excretion of follicle-stimulating hormone positive to 96 and 192 mouse units, and reported high excretion in another.

TABLE I

BLOOD ELECTROLYTE LEVELS

Case number	Plasma-chlorides (as NaCl *milligrams*/100 *millilitres*) (Normal=570 to 620)	Serum-sodium (*milligrams*/100 *millilitres*) (Normal=325 to 350)	Serum-potassium (*milligrams*/100 *millilitres*) (Normal=16 to 20)
1	570, 556	327	17
3	580	342	—
7	556	335	—
8	600, 590	332	17·5
9	580, 600	340	16

Adrenal function—In no case was abnormal pigmentation apparent. Tests of adrenal function were divided into three categories: 1) electrolyte estimations, 2) tests of carbohydrate metabolism and 3) tests of 17-ketosteroid excretion. The plasma-chloride and serum-sodium were estimated in five patients, and the serum-potassium in three. The results were normal (Table I).

The water excretion test (Robinson, Power and Kepler 1941) was performed on three patients. All had a delayed diuresis after the ingestion of a large volume of fluid, but the indices derived from applying the formula in the second part of the test were normal (Table II).

TABLE II
WATER EXCRETION TEST

Case number	Volume of night urine (*millilitres*)	Greatest volume of hourly urine (*millilitres*)	Index
7	435	315	38
8	300	210	35
9	360	270	31

TABLE III
GLUCOSE TOLERANCE TEST

Case number	Blood sugar (*milligrams*/100 *millilitres*)					
	Fasting	½ hour	1 hour	1½ hours	2 hours	2½ hours
1	98	125	135	139	130	124
	85	112	120	140	134	118
2	80	115	90	75	70	—
3	83	140	96	69	72	82
7	71	96	131	148	129	—
8	65	120	135	130	85	—
9	80	160	130	130	90	—

TABLE IV
INSULIN TOLERANCE TEST

Case number	Blood-sugar (*per cent of fasting value*)						
	Fasting (*milligrams*/100 *millilitres* in parentheses)	20 minutes	30 minutes	45 minutes	60 minutes	90 minutes	120 minutes
1	100 (106)	64	58	48	72	83	92
	100 (100)	72	41	37	77	110	105
2	100 (76)	80	60	66	68	102	105
5	100 (106)	59	43	57	63	70	120
7	100 (70)	71	55	70	73	105	117
8	100 (75)	80	53	80	87	75	100
9	100 (90)	72	50	78	84	89	90

Adrenal cortical hormone function was assessed by the glucose tolerance test and the insulin sensitivity test. The standard two-hour tolerance test with 50 grammes of oral glucose was used. Insulin tolerance was tested by the method of Fraser, Albright and Smith (1941). Sugar determinations were made by the micro-method of Folin (1922) with capillary blood. The results are given in Tables III and IV, and on the whole are normal.

The level of neutral urinary 17-ketosteroids was determined by the Fraser, Forbes, Albright, Sulkowitch and Reifenstein (1941) method, in which spectrophotometric correction is made for extraneous colours. The results are given in Table V, and are well below normal limits. Patients in whom the disease was advanced had excretions approaching those found in panhypopituitarism.

TABLE V

URINARY 17-KETOSTEROID DETERMINATIONS

Case number	17-ketosteroid excretion (*milligrams in 24 hours*)
1	1·0, 0·4, 1·1, 1·3
2	2·5, 4·5
3	4·2, 5·5
4	2·3
5	4·8
6	1·7
7	1·8
8	1·2
9	3·1

Thyroid function—The basal metabolic rate and serum-cholesterol levels were estimated in seven patients (Table VI). Waring, Ravin and Walker (1940) reported, as a rule, low basal metabolic rates and normal cholesterol levels. Only two patients in the series had abnormally low basal metabolic rates, but raised cholesterol levels were found more frequently and appeared

TABLE VI

BASAL METABOLIC RATE AND SERUM CHOLESTEROL

Case number	Basal metabolic rate (*per cent*)	Serum-cholesterol (*milligrams per* 100 *millilitres*) (*normal* 120–220 *milligrams*/100 *millilitres*)
1	−34, −48	335, 360
2	−12, −8	180
3	+38, +27	210
5	—	180
6	+10	—
7	−4	310
8	+9	200
9	−9	205, 280

to parallel the severity of the condition. The patient in Case 3, whose basal metabolic rate was raised and serum cholesterol normal, had an auricular flutter.

Parathyroid function—The similarity between the cataract occurring in dystrophia myotonica and that occurring in the tetany of hypoparathyroidism has been noted by many workers. Calcium metabolism has been studied in the former condition. Waring, Ravin and Walker

(1940) reported normal serum-calcium and serum-phosphorus levels in all their patients, and Milhorat and Toscani (1939) reported a normal calcium and phosphorus balance in one patient whom they examined. The serum-calcium and serum-phosphorus levels were determined in most of the patients in the series, and in some cases the alkaline phosphatase was estimated (Table VII). The results were normal.

TABLE VII

Case number	Serum-calcium (*milligrams*/100 *millilitres*)	Serum-phosphorus (*milligrams*/100 *millilitres*)	Plasma alkaline phosphatase (*King-Armstrong units*) (normal, 4–13)
1	10·7, 10·5, 9·1	4·0, 3·3	17, 22
2	10·7	3·6	3·2
3	10·4	3·2	6
5	10·8	—	—
6	10·8	—	—
7	10·3	4·0	8·0
8	10·7, 9·9	2·0, 3·0	6·9
9	10·1	2·2	4·0

Since serum-calcium levels as low as those occurring in tetany due to hypoparathyroidism have never been recorded in a patient with dystrophia myotonica, and since no abnormality in calcium or phosphorus metabolism has yet been demonstrated, it appears that decreased parathyroid function is not a factor in this disease.

CHANGES IN THE SKULL IN DYSTROPHIA MYOTONICA

Few authors have referred to the bone changes in the skull in dystrophia myotonica. Scharnke and Full (1920) reported large frontal sinuses in the presence of a normal pituitary fossa. Rouquès (1931) reported radiographic abnormalities in the skull in four patients. In three there was distinct thickening of the calvarium; large frontal sinuses occurred in two; in two the pituitary fossa was small, and in two the fossa was abridged by calcification. Fagin (1946) reported hyperostosis frontalis in two patients and Correia de Oliveira and Mosinger (1951) discussed hyperostosis frontalis interna associated with the disease.

In three papers, Caughey and Brown (1950) and Caughey (1952*a*, 1952*b*) discussed the skull changes and stressed the frequency of this finding. Of fifteen cases with skull changes, ten were in males and five in females. Since 1952 several new cases have been observed. (Case records in Appendix 1.)

The radiological features observed (Fig. 4) have been a general thickening of the whole calvarium, hyperostosis frontalis and fronto-parietalis, a small pituitary fossa, a general increase in the air cells of the frontal and ethmoidal sinuses with pneumatisation of the dorsum sellae and, in some, prognathism. In some cases most of these features may be present, in others only one or two (Fig. 5). A résumé of the skull defects in twenty-two cases is seen in Table VIII.

These skull changes have been observed in the dystrophic generation in patients with the fully developed disorder. In this series no record has been found of skull changes presenting in those patients, usually of the first generation, who present with cataract alone, nor in those members of the third generation who present with congenital physical and mental defects, as described by Caughey and Barclay (1954). The incidence of the skull changes in this series

of thirty-seven cases with the fully developed disorder, who have had a skull radiograph, was twenty-two (59·5 per cent). The sex incidence was thirteen men and nine women. The ages ranged from twenty-seven to fifty-one years.

The incidence of hypogonadism is difficult to assess, especially in the women. It will be observed in Table VIII that eight patients had hypogonadism. This diagnosis was made on the clinical testing and the examination of the testicles. In two, gonadal biopsy revealed atrophy of the seminiferous tubules and of the interstitial elements.

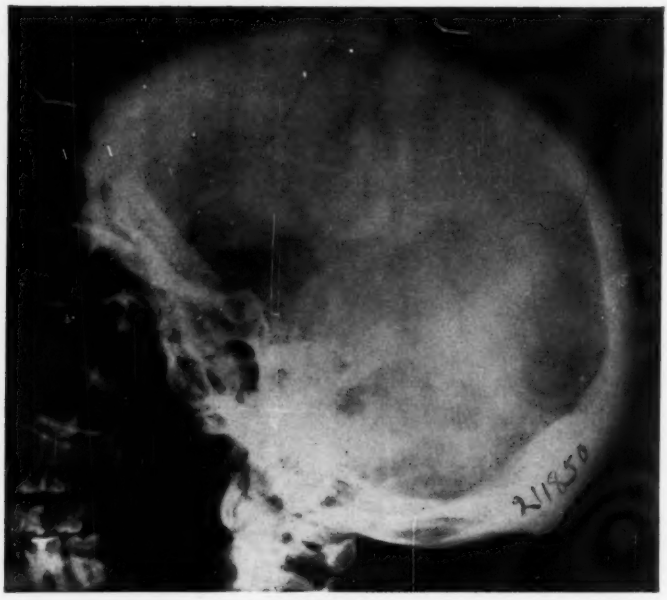

FIG. 4
Dystrophia myotonica with hyperostosis calvariae diffusa.

These changes in the skull may at best be described as acromegaloid changes. In one patient reported above, with well marked acromegaloid changes, there was a large pituitary gland and an enlarged pituitary fossa. These changes suggest some increased activity of growth hormone at some period in the natural history of this disease.

DISCUSSION

The occurrence of hyperostosis cranii in men and women alike who have dystrophia myotonica suggests that a study of dystrophia myotonica may yield a clue to our understanding of the syndrome of hyperostosis cranii.

In dystrophia myotonica the striking endocrine feature is the gonadal atrophy which is common to both sexes. The low levels of urinary 17-ketosteroids that have been reported in the men suggest that there is a failure of the androgenic function of the gonads and of the adrenals. In the two women in the series, also, the same low levels support the suggestion of a failure of the androgenic function of the adrenals.

It is possible that, in consequence of the failure of androgenic function, the anterior pituitary gland responds by an increase of gonadotrophic activity and also of growth hormone in some cases. The hyperostosis cranii is a likely manifestation of the increased activity of growth hormone.

Animal studies—In order to develop the argument it is necessary at this stage to discuss some aspects of the gonadal-pituitary function.

Castration of rats and mice leads to over-activity of gonadotrophic basophil cells which in time may go on to form pituitary adenomata. Griesbach and Purves (1956) reported basophil adenomata in seven out of eight rats castrated at nine months and examined twenty-seven months later. In rats castrated at birth Houssay, Houssay, Cardeza and Pinto

FIG. 5
Skull in case of dystrophia myotonica with hyperostosis frontalis and small pituitary fossa.

(1955) reported a high incidence of basophil adenomata in eighteen months to two years. Griesbach and Purves (1956) observed adenomata fifteen months after castration of rats six weeks old.

Effects of testicular secretions upon the pituitary function in man—The testes exert a regulating action upon the output of gonadotrophins by the pituitary gland during the early phases of adolescence when the quantities of urinary gonadotrophins are small (Hamilton 1948). In three boys with a follicular-stimulating hormone level of 3·5 mouse units before castration, the level of follicular-stimulating hormone rose to abnormally high levels of 5·0 mouse units or more after castration. Such high levels are not seen during normal adolescence (Catchpole

TABLE VIII

SKULL DEFECTS IN DYSTROPHIA MYOTONICA

Case number	Age	Sex	Status of dystrophia myotonica	Hypogonadism	Calvarium
1	45	M	Fully developed	Yes	Thickened
2	42	M	Fully developed	Yes	Normal
3	26	M	Fully developed	Reported normal	Thickened
4	33	F	Fully developed	Three children	Thickened
—	27	M	Fully developed	No	Thickened
5	32	M	Fully developed	No	Normal
6	41	M	Fully developed	Yes ++	Normal
7	51	F	Fully developed	Yes	Thickened
8	28	M	Fully developed	Yes	Thickened
9	33	M	Fully developed	Yes	Small, thickened
10	45	F (single)	Fully developed	?	Thickened
11	47	F	Fully developed	?	Thickened
12	42	F (single)	Fully developed	—	Marked thickening
—	42	M	Fully developed	Yes	Marked thickening
13	43	M	Fully developed	Yes	Thickened
14	35	F	Fully developed	No	Thickened
15	—	F	Fully developed	No	Thickened
16	44	M	Fully developed	?	Thickened
17	40	M	Fully developed	?	Thickened
18	49	F	Fully developed	?	Thickened in frontal
19	43	F (single)	Fully developed	?	Thickened somewhat
20	28	M	Fully developed	—	Thickened

1942), and it suggests that in early adolescence the testicular function restrains the production of gonadotrophins by the pituitary gland. Catchpole, Hamilton and Hubert (1942) found in a study of eunuchs that the average urinary excretions of gonadotrophins was 40 or more mouse units. This is larger than that excreted by normal young men (Werner 1943). Hamilton, Catchpole and Hawke (1945) showed that the high level of urinary gonadotrophins may persist for as long as fifty years after castration. It is the usual finding in men who have been castrated early in life and live to an old age. Thus there is evidence of an overactivity of basophil gonadotrophic cells of the anterior lobe in man, like that which occurs in rats and mice.

Acromegaloid features in hypogonadism have been reported by Koch (1921), Wagenseil (1927) and McCullagh and Renshaw (1934). Hamilton, Catchpole and Hawke (1945) found two examples in a series of 200 eunuchs. No case is described in the literature in which gross acromegaly has developed. There does, however, seem to be adequate evidence to

TABLE VIII—*continued*

Hyperostosis frontalis interna or fronto-parietalis	Pituitary fossa	Sinuses	Prognathism
H.F.P.	Small	Dorsum sellae pneumatised	No
No	Small	Frontals +++	No
H.F.I.	Very small	Frontal deep	—
H.F.P.	Small	Dorsum sellae pneumatised	No
H.F.I.	Small	Normal	No
No	Small	Large	—
No	Small	Frontal deep and extensive	Yes
Extensive H.F.P.	Very small, calcified on floor	Normal	No
Extensive H.F.P.	Very small	Dorsum sellae pneumatised. Others extensive and deep	No
No	Very small	Extensive, deep. Dorsum sellae pneumatised	Yes
Marked H.F.P.	Small	Sphenoidals large	Yes
H.F.I.	Small	Normal	No
H.F.I.	Small	—	—
H.F.I.	Small and bridged over	—	No
Marked H.F.I.	Enlarged	Extensive frontal	Yes ++
H.F.I. early	Small	Normal	No
H.F.I.	Normal	Normal	—
H.F.I.	Small	Normal	No
H.F.I.	Normal	Normal	No
H.F.I.	Small	Normal	No
H.F.I.	Small	Normal	No
H.F.I.	Small	Dorsum sellae pneumatised	—

suggest that when the restraining action of the testes is removed, the pituitary may excrete an excess of growth hormone.

In an attempt to correlate hypogonadism with the development of pituitary tumours in man, a search was made of some of Cushing's (1912) classical case records and records of fifty other cases of pituitary tumour (Caughey 1957). Cushing mentioned a married woman with a pituitary tumour in whom there was evidence of gonadal defect. At operation both ovaries were cystic and small. He also reported the case of a single woman of twenty-six with a pituitary tumour who had had a period at fourteen years and thereafter amenorrhoea. At a gynaecological operation she was found to have bilateral cystic fibrous ovaries.

Two of the personal cases reported (Caughey 1957) were in women who had had bilateral oophorectomy over twenty years before and subsequently developed pituitary tumours. Two men with hypogonadism of long standing developed pituitary tumours, and one patient with

dystrophia myotonica, gonadal atrophy, hyperostosis cranii and acromegaloid changes had an enlarged pituitary fossa and an enlarged pituitary gland.

From these facts it seems evident that after the development of hypogonadism in males and in females, the pituitary gland usually responds by an increase in the gonadotrophic activity, both in animals and in man. Less often in man there may be an increase in the output of growth hormone leading to acromegaloid features.

Effects of growth hormone on the skull—It is well recognised that generalised overgrowth in the human may eventually be associated with disproportion of skeletal parts and localised bony overgrowths which are the most characteristic features of acromegaly. Similar changes have been reproduced in different animals: in the dog by Putnam, Benedict and Teel (1929) and by Evans, Simpson, Meyer and Reichert (1933), and in the guinea pig and mice by Silberberg and Silberberg (1943). Asling, Simpson, Moon, Li and Evans (1955) reported the details of some of these changes in rats. In the skull there were certain characteristic changes like those observed in acromegaly. There was increased length and breadth of skull of the injected rats with an increase in the height of the ridges at muscular attachments, and general thickening of bone. Section through the bone showed clearly increased thickness of the laminae. The haemopoietic marrow was expanded within the diplöe.

Hyperostosis cranii in dystrophia myotonica—It is suggested that, in consequence of the failure of androgenic function of the gonads and of the adrenal glands, the usual restraining influence on the anterior pituitary gland is removed, one result of which is the high levels of follicular-stimulating hormone. Also in some of these cases there is a release of growth hormone which accounts for the excessive sinus formation—prognathism and the hyperostosis cranii. The smallness of the pituitary fossa can be explained by involvement in the hyperostosis.

The marked tendency to hyperostosis cranii in acromegaly lends support to the suggestion that excessive growth hormone accounts for the hyperostosis. In women with the Morgagni syndrome, with hirsutism and hyperostosis cranii, the virilism could be brought about by the overactivity of the adrenal cortex. Excessive androgens in turn suppress normal oestrogenic function of the gonads and the adrenals. Consequently, restraint is removed from the pituitary growth function and hyperostosis cranii develops.

Hence in these three conditions in which hyperostosis often occurs, a common factor is the releasing of the usual restraint from the growth hormone, which in turn could account for the hyperostosis cranii common to the three.

SUMMARY

1. The clinical features of hyperostosis cranii are briefly reviewed. In large series of cases the syndrome has been found to occur almost entirely in females.

2. In recent studies of dystrophia myotonica, it is apparent that hyperostosis cranii is one of the variable features of the disorder. This disease occurs equally among males and females and the hyperostosis cranii also is distributed equally among males and females.

3. Hyperostosis cranii also occurs in patients with Morgagni's syndrome, with acromegaly, and as "senile hyperostosis."

4. The etiology of hyperostosis is still a matter for speculation. More recent studies have focused attention on the endocrine system, and it seems probable, in view of the sex distribution in dystrophia myotonica, that the key to the problem may be found in this disorder.

5. In dystrophia myotonica the characteristic skull changes are hyperostosis cranii, a small pituitary fossa, excessive sinus formation and prognathism. These are acromegaloid changes. Gonadal atrophy is a common feature and endocrine study suggests that the endocrine defect is primarily a failure of the androgenic function of the adrenals and the testes.

6. In rodents and in humans ablation of the gonads leads to overactivity of gonadotrophic cells and, at times, of somatotrophic cells. Sometimes pituitary tumours develop.
7. Acromegaloid features may occur in eunuchs, and it is likely that the acromegaloid changes in dystrophia myotonica are of the same order from overactivity of growth hormone.
8. In animals excess of growth hormone produces thickening of the skull.
9. In dystrophia myotonica, acromegaly, and Morgagni's syndrome, it is suggested that hyperostosis cranii is an expression of unrestrained activity of growth hormone.

APPENDIX 1

CASE REPORTS

FAMILY I

Case 1—Myopathy, myotonia, bilateral cataract, premature frontal baldness, hypogonadism, hypothyroidism, small pituitary fossa and hyperostosis frontalis.

The patient was an unmarried man of forty-five, pensioned owing to disablement. At the age of about twenty-seven he had noticed wasting of the arms, legs and neck muscles. This had progressed steadily and for the last three years he had been completely disabled, being unable to raise his head or to stand alone. Five years after the onset of muscle wasting he found difficulty in relaxing his grasp, and about the same time his vision began to fail because of bilateral lenticular opacities. Cataracts were successfully treated five years later. Seven years after the onset he had to give up farming on account of increasing weakness. Frontal baldness had developed in his early twenties. He first shaved at the age of seventeen years, and since then had not had to shave more than every third day. The hair on his body had become soft and scanty during the past ten years. Sexual power and libido had deteriorated, but he still had some potency and occasional nocturnal emissions. He had complained of the cold in recent years. His parents and grandparents were healthy. One brother, aged forty-one, had bilateral lenticular opacities but no other evidence of the disease. Another brother and a sister were normal. An aunt on the maternal side had cataracts, but was not examined.

On examination the patient's measurements were: height, 5 feet 10 inches; span, 5 feet 10 inches; vertex to symphysis pubis, 2 feet 11 inches; symphysis pubis to sole, 2 feet 11 inches. The facial hair was soft and scanty on the chin and moustache area. The pubic hair was of female distribution, the axillary hair was normal, and there was no hair on the legs. The skin of his fingers was shiny and dystrophic in appearance. He was unable to sit without assistance, and required help when walking. Visual acuity was reduced, as a cataract had been removed from each eye. The facial muscles were wasted and very weak, and there was almost complete atrophy of both sternomastoid muscles. There was great wasting and weakness of all the muscles of the forearms. The abdominal muscles were weak, and the lower limbs were wasted and weak in all movements. The gait when assisted was unsteady and of a " slapping " and " steppage " type. When he was seen about twelve years before, there had been myotonia of the grasp, but, probably because of excessive weakness, this was now slight. There was slight mechanical myotonia in the tongue and the thenar and hypothenar eminences. All the deep reflexes were lost. Sensory appreciation was normal. The testes were soft and very small. His mental state was good. He was co-operative and not subject to any variations in mood. The cardiovascular system was normal, with a blood pressure of 150/75. Other systems were normal.

Investigations—The blood count was normal and the Kahn reaction negative. The cerebrospinal fluid was normal. The basal metabolic rate was −48 per cent and −34 per cent. The serum-cholesterol was 360 milligrams per 100 millilitres, the total non-protein nitrogen 33 milligrams per 100 millilitres, the serum-chlorides 556 milligrams per 100 millilitres (as NaCl), the serum-calcium 10·7, 10·5 and 9·1 milligrams per 100 millilitres, serum-sodium 327 milligrams, and serum-potassium 17 milligrams per 100 millilitres. The serum acid phosphatase was 1·2 units, and alkaline phosphatase 22 King-Armstrong units. Tests of glucose tolerance and insulin tolerance in 1947 and 1949 showed a delayed return of the blood sugar to a normal level after 50 grammes of glucose, and a delayed fall in the blood sugar level after insulin (Tables III and IV). The excretion of follicle-stimulating hormone was positive to 96 mouse units. The potassium resistance test for adrenal cortical function (Cutler, Power and Wilder 1938) gave an equivocal result. The 17-ketosteroid excretion was 1·3 and 1 milligram per 100 millilitres in twenty-four hours. The electrocardiograph showed elevation of the ST segment in leads I and II, and slight ventricular myocardial damage seemed probable (Dr E. Roche). Radiologically the lung fields were clear and the heart shadow normal. A radiograph of the skull showed the vault to be normal in shape, and the calvarium thickened, with hyperostosis interna frontalis et parietalis; the sinuses were within normal limits, the mandible was normal and the sella turcica small, with a pneumatised dorsum sellae. The pineal body was calcified.

FAMILY II

Members of two families with the same father were investigated. The father was examined and had a bilateral posterior polar cataract but no other signs of dystrophia myotonica. By his first wife he had a son (Case 2), and a daughter who was not examined. By his second wife he had three sons and a daughter, all of whom had the complete picture of the disorder. Two of them (Cases 3 and 4) are described.

Case 2—Myopathy, myotonia, bilateral cataract, frontal baldness, hypoganadism and a small pituitary fossa.

This patient was a retired farmer aged forty-two. In 1941 he had become aware of difficulty in relaxing his grasp, soon followed by weakness and wasting of the forearm, leg and neck muscles. The wasting and weakness had progressed and the myotonia had persisted. For four years there had been impairment of sexual power and libido, with complete loss of potency in the last six months. Frontal baldness began in his early twenties. He had lately become irritable and less reliable.

On examination, he had extensive body hair and normal facial hair. There was general wasting of the facial, temporal and sternomastoid muscles, the latter giving a rounded swan-like appearance to the neck. The deltoid muscles were hypertrophied but weak, and there was severe wasting and weakness of the forearms and upper arms, the small muscles of the hands being unaffected. There was great wasting of the legs, and to a lesser extent of the thighs. All the deep reflexes were much impaired. The grasp was myotonic on both sides, and myotonia of the tongue, thenar, hypothenar and calf muscles was present on percussion. Visual acuity was reduced to 6/12 in both eyes by lenticular opacities. The testes were small and soft. The cardiovascular system was normal.

Investigations—The blood Kahn test was negative and a blood count was normal. The serum-calcium was 10·7 milligrams, serum-phosphorus 3·6 milligrams, and serum-cholesterol 180 milligrams per 100 millilitres. The cerebrospinal fluid was normal, the basal metabolic rate was −12 per cent and −8 per cent. The electrocardiograph was normal. The glucose tolerance and insulin tolerance tests gave normal results (Tables III and IV). The excretion of 17-ketosteroid on two estimations was 2·5 and 4·5 milligrams in twenty-four hours. A radiograph of the chest was normal. The skull showed a normal vault, large frontal sinuses and a normal sella turcica. The mandible and the pineal body were not seen.

Case 3—Myotonia, myopathy, auricular flutter.

An unmarried man aged twenty-six, a panel beater, developed palpitation and breathlessness and was admitted to hospital (1945), where auricular flutter was diagnosed. For two years he had noticed difficulty in relaxing his grasp, and weakness of his wrists and legs. Frontal baldness began to develop at the age of twenty-one. The sexual functions were unimpaired.

On examination, he was slightly built. The body hair and pubic hair were normal. The facies was myopathic, and the neck rounded and swan-like from wasting of the sternomastoid muscles. The forearms were wasted, and the extensors of the wrists weak. The deep reflexes of the arms were absent; the knee jerks were reduced. There was myotonia of the grasp and myotonia on percussion of the tongue, thenar and hypothenar eminences, and calves. The testes were normal. The visual acuity was normal, and there were no lenticular opacities. The pulse rate was 110 per minute, the rhythm was regular, and the vessels were soft. The apex beat was in the fifth space, three inches from the mid-line. The heart sounds were normal, and there were no murmurs. The blood pressure was 115/85. An electrocardiograph showed an irregular rhythm with a 4:1 to 7:1 flutter. The ST segment was normal.

Investigations—The blood count was normal, and the Kahn reaction negative. The serum-calcium was 10·4 milligrams, serum-phosphorus 3·2 milligrams, and serum-cholesterol 210 milligrams per 100 millilitres. The basal metabolic rate was +38 per cent and +27 per cent. The serum acid phosphatase was 2 units. Glucose tolerance (Table III) and insulin tolerance were normal. The excretion of 17-ketosteroid on two estimations was 4·2 milligrams and 5·5 milligrams in twenty-four hours. A radiograph of the chest was normal. The skull showed a vault of normal shape; the bones were thickened, especially in the posterior parietal region. There was parietal hyperostosis interna extending to the frontal region. The frontal sinuses were deep and the sella turcica was normal. The mandible and the pineal body were not seen.

Case 4—Myotonia, muscular dystrophy, bilateral cataract.

A married woman, aged thirty-three, had noticed a difficulty in relaxing her grasp for twelve years, and six or seven years later a weakness and wasting of her right leg. Soon afterwards the weakness and wasting had become apparent in the left leg, upper limbs, neck and face. Next she found difficulty in holding her back straight, and, at times, a tendency to overbalance. For three years she had noticed deterioration of her vision, and eighteen months ago the vision in her right eye had failed completely, and a cataract was excised. The left eye subsequently failed and a cataract was removed. She had had

three children. The first had a cleft palate, and died of meningitis. The second had a cleft palate and hare lip, and the third child was alive and well.

Examination showed a myopathic facies, with wasting of all the facial muscles; the neck was swan-like from complete wasting of the sternomastoids. There was wasting of the forearms, with weakness which was more marked in the dorsiflexors of the wrists. The muscles of the legs were wasted, and the dorsiflexors of the feet weak. The grip was myotonic and there was myotonia on percussion of the tongue, thenar and hypothenar eminences. All the deep reflexes of the lower limbs were absent. Before her operation for cataract there were bilateral lenticular opacities; on slit-lamp examination these were punctate or small and scale-like, some of those situated under the cortex being bluish-green. Outside the nucleus they had gradually increased so that both lenses were opaque (Mr W. A. Fairclough). A radiograph of the skull showed a normal-shaped vault; the calvarium was thickened throughout, with marked hyperostosis frontalis interna and hyperostosis parietalis, somewhat resembling that seen in Paget's disease. The sinuses were within normal limits, with pneumatisation of the dorsum sellae. The sella turcica was within normal limits. The pineal body was calcified. Laboratory investigations were incomplete. The 17-ketosteroid excretion was 2·3 milligrams in twenty-four hours.

FAMILY III

Case 5—Myotonia, myopathy, cataract, frontal baldness.

A returned soldier aged thirty-two had noticed difficulty in relaxing his grip while a prisoner of war in 1944, and this was soon followed by wasting and weakness of the right shoulder muscles. The wasting went on to involve the muscles of the face, neck, forearms, shoulder girdles and legs. His vision had recently deteriorated. There had been no impairment of sexual power or libido.

Examination showed extensive frontal baldness and a myopathic facies, with early wasting of the facial muscles. The sternomastoid muscles were completely wasted, and there was great wasting of the left deltoid and pectoral muscles, and of the spinati and trapezii. The lower limbs were normal. There was myotonia of the grip and myotonia on percussion of the tongue, the thenar and hypothenar eminences, the deltoids and the flexors of the forearms. The knee jerks were diminished and the right ankle jerk was absent. Visual acuity was unimpaired but both eyes showed early cataract, with a few striae radiating from the posterior pole of the right lens and a few minute opacities in the left lens. The slit-lamp examination revealed multiple punctate opacities of various sizes in the anterior cortex of both lenses, more marked at the equator. A few of the opacities were greenish in colour.

Investigations—A blood count was normal, and the blood Wassermann reaction negative. The cerebrospinal fluid was normal. The serum-calcium was 10·8 milligrams per 100 millilitres, and serum-cholesterol 180 milligrams per 100 millilitres; 17-ketosteroid excretion was 4·8 milligrams in twenty-four hours. Insulin sensitivity was normal (Table IV). Biopsy from the left deltoid muscle showed irregular changes in the muscle fibres, some of which were hypertrophic and many wasted, and an increase of fibrous tissue. There was loss of the transverse striations and multiplication of the nuclei.

FAMILY IV

Case 6—Complete picture of dystrophia myotonica: myotonia, wasting, cataracts, failure of sexual power and libido, left bundle branch block.

A carpenter aged forty-one had noticed failure of sexual power for seven years, and this went on to complete loss of potency and libido. Four years later his grasp became difficult to relax, there was weakness of the arms and legs, and difficulty in swallowing, and his speech became slurred.

On examination he was bald, with a myopathic facies. His speech was somewhat slurred and thick. The sternomastoid muscles were completely wasted. There was great wasting and weakness of all four limbs and of the abdominal muscles. Voluntary myotonia affected the grasp of both hands, and there was myotonia on percussion. All the deep reflexes were absent. The pubic hair was scanty. The testes were small and soft, and the prostate gland was small. Visual acuity was normal. Slit-lamp examination revealed multiple punctate subcapsular opacities, longer and more numerous at the periphery. A few were green. There were posterior cortical radial opacities in both lenses. The pulse was slow and regular. The heart was not enlarged, and there was reduplication of the second sound at the apex. The blood pressure was 100/55.

Investigations—A blood count was normal, and a blood Kahn test was negative. The cerebrospinal fluid was normal. The 17-ketosteroid excretion was 1·7 milligrams in twenty-four hours. A gastric test meal showed a low total acidity. Electro-cardiography showed the heart rate to be 50 per minute: the P waves were of low voltage, the PR interval 0·26 seconds, the QRS complexes widened, and the ST segment depressed in leads I and II and elevated in lead V_4; T was biphasic in leads I and II, and high in lead V_4. These findings suggested an impaired function of the sino-auricular node and

myocardial damage affecting bundle conduction, with a block of the left bundle branch. An electrocardiograph taken two weeks later revealed no change. A radiograph of the chest was normal. The skull showed a normal vault with well marked venous lacunae; the frontal and sphenoid sinuses were extensive and deep, the latter extending into the posterior clinoid processes. The mandible was elongated. The sella turcica was possibly small, but showed no calcification within; the dorsum sellae was completely pneumatised. The pineal body was not seen.

FAMILY V

Case 7—Myopathy, myotonia, bilateral cataract, small pituitary fossa and hyperostosis frontalis.

A married woman aged fifty-one had noticed weakness of her neck muscles since the age of thirty. In the past five years there had been progressive wasting and weakness of the forearms and legs, so that she had been bedridden for a year. At times she had noticed some difficulty in relaxing her grasp, but this was not troublesome. Her vision had not failed noticeably, but there had been loss of libido for several years. She had two sons, the younger—aged twenty-eight years—having the fully developed disease (Case 8). The elder son was well. There was no history of cataract in the family.

On examination she had grey hair, no baldness, and a myopathic facies. Her speech was slurred. The body hair and eyebrows were somewhat scanty, but of normal female distribution. The skin was soft and of fine texture. There was some wasting of the facial muscles. The sternomastoid muscles were almost completely atrophied and were powerless. There was great weakness and wasting of the forearms and legs. Myotonia was slight. All the deep reflexes were reduced, and the ankle jerks absent. There were bilateral posterior polar cataracts. The mental state was normal, and she was of average intelligence. The cardiovascular system was normal.

Investigations—The serum-calcium was 10·3 milligrams and serum-phosphorus 4 milligrams per 100 millilitres. The serum-sodium was 335 milligrams, serum-chlorides 556 milligrams (as NaCl), and serum cholesterol 310 milligrams per 100 millilitres. A glucose-tolerance test showed a delay in the return of the blood sugar to a normal level. Insulin sensitivity was normal (Tables III and IV). The excretion of follicle-stimulating hormone was strongly positive to 96 mouse units. The 17-ketosteroid excretion was 1·8 milligrams in twenty-four hours. The water excretion test for adrenal cortical function (Robinson, Power and Kepler 1941) was suggestive of impaired function. The volume of the night urine was 435 millilitres, and that of the largest day specimen 315 millilitres, giving an index of 38. The basal metabolic rate was −4 per cent. An electrocardiograph showed low voltages throughout, a left bundle branch block, and probably a first degree of heart block. A radiograph of the chest was normal. The skull showed the vault to be normal in shape, but possibly enlarged from thickening of all the membranous bones; there was extensive hyperostosis frontalis interna. The thickening was somewhat patchy, resembling that seen in Paget's disease. The sinuses and mandible were normal. The sella turcica was small, with calcification near the floor; there was no pneumatisation of the dorsum sellae. The pineal body was not seen.

Case 8—Myopathy, myotonia, cataract, hypogonadism, mental retardation, small pituitary fossa, and hyperostosis frontalis.

This patient, a pensioner aged twenty-eight, was the younger son of the previous patient (Case 7). At school he was backward but did not require special schooling. On leaving school at the age of thirteen he was unable to take up any regular employment. At seventeen he noticed difficulty in relaxing his grasp, soon followed by weakness and clumsiness of his arms, legs and neck muscles. The weakness and wasting progressed slowly. For two years before examination his vision had been deteriorating.

On examination he was a dark, swarthy man of inferior intelligence. His facies was myopathic, with a slow lingering smile. There was early recession of the hair in the frontal region, but the body hair was normal and of male distribution. His speech was slurred and indistinct. There was wasting of the sternomastoid muscles and of the muscles of the forearms and legs. There was marked myotonia of the grasp and, on percussion, of the tongue and small muscles of the hands. The knee and ankle jerks were absent. There was bilateral polar cataract. The testes were small and soft, but had normal sensation. The scrotum and penis were of normal size. The body dimensions were: height, 5 feet 5½ inches; span, 5 feet 5½ inches; vertex to pubis, 2 feet 9 inches; pubis to soles, 2 feet 8½ inches.

Investigations—The serum-sodium was 332 milligrams, and serum-potassium 17·5 milligrams per 100 millilitres; the serum-cholesterol 200 milligrams, serum-calcium 9·9 milligrams and the serum-phosphorus 2·0 milligrams per 100 millilitres. Glucose tolerance and insulin sensitivity (Tables III and IV), and the clinical response of the patient to insulin, were normal. The 17-ketosteroid excretion was 1·2 milligrams in twenty-four hours. The water excretion test (Robinson, Power and Kepler 1941) produced 300 millilitres of night urine, and the greatest hourly volume of day urine after fluid was 210 millilitres, giving an index of 35. The excretion of follicle-stimulating hormone was positive to

96 mouse units. An electrocardiograph showed a PR interval of 0·17 seconds, and a very small R wave in leads V_2 and V_3, with the probability of myocardial damage (Dr E. G. Sayers). A skull radiograph showed the vault to be normal in size; all the membranous bones were thickened, with extensive hyperostosis frontalis interna and hyperostosis parientalis interna. The sclerosis was patchy, to some extent resembling that of Paget's disease. The sinuses were extensive and deep. The sella turcica was small, and the dorsum sellae thick and partly pneumatised. The pineal body was possibly calcified. The intelligence quotient by Wechsler's performance test was 74.

FAMILY VI

Case 9—Myopathy, myotonia, hypogonadism, mental retardation, and a small pituitary fossa.

A grocer aged thirty-three had always been a frail individual and afraid of other boys. At school he had been backward. His occupational history was unsatisfactory and for the last year he had been unemployed. He had first noticed difficulty in relaxing his grasp when aged thirteen. At the age of fifteen he had noticed that his arm and leg muscles were becoming weaker and were wasting. The difficulty with his grip had become increasingly great. He had begun shaving at the age of twenty-one, and at thirty-three shaved every third day. His vision had not deteriorated. He felt the cold very much. Neither of his parents, to his knowledge, had any wasting, muscle disability or cataract. A paternal cousin had wasting of his arms and legs. A brother and sister of the patient were reported to be well.

On examination he was thin, with a disinterested look, and below the average in intelligence. The head hair was dark, fine and scanty, and the eyebrows were scanty. The facial hair was scanty and confined to the moustache and chin areas. The axillary and pubic hair were also scanty, the latter being of female distribution. The hair on the legs was fine but of normal distribution. The skin was dry and atrophic, with numerous melanomata. The thyroid gland was not palpable. There was marked myotonia of the grip, and myotonia of the tongue and thenar eminences on percussion. The facies was myopathic, and there was wasting of the sternomastoids and, to a lesser degree, of the limb muscles. The deep reflexes were normal. No cataract was present. The prostate gland was small. The cardiovascular system was normal.

Investigations—The blood Kahn test was negative. The serum-sodium was 340 milligrams, serum-potassium 16 milligrams, and serum-chloride 580 milligrams per 100 millilitres; the serum-cholesterol was 280 milligrams and the serum-calcium 10·1 milligrams per 100 millilitres. Glucose tolerance and insulin sensitivity (Tables III and IV), and the clinical reaction to insulin, were normal. The 17-ketosteroid excretion was 3·1 milligrams in twenty-four hours. The water excretion test (Robinson, Power and Kepler 1941) produced 360 millilitres of night urine, and the greatest hourly day urine after fluid was 270 millilitres, giving an index of 31. Excretion of follicle-stimulating hormone was positive to 96 mouse units. An electrocardiograph showed some slurring of R in leads I and II, probably representative of myocardial damage. A radiograph of the skull showed a small, globoid and microcephalic vault. The bones were thick but of normal density, with marked venous lacunae. The sinuses were extensive and deep, especially the sphenoids, which extended into the posterior clinoid processes. The mandible was elongated. The sella turcica was very small, but showed no calcification within. The dorsum sellae was pneumatised. The pineal body was not seen.

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PAROSTEAL OSTEOGENIC SARCOMA OF BONE

Report of a Case

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In 1949 and in 1951 Geschickter and Copeland described as " parosteal osteoma " a tumour occurring in adults, usually at the back of the lower end of the femur and bulging into the popliteal fossa. This was considered to start as a benign proliferation of ossifying fibrous tissue arising in the region of the periosteum, resembling myositis ossificans in some respects but involving neighbouring bone. Over a number of years this tended to evolve into a malignant tumour histologically akin to sclerosing osteogenic sarcoma. In 1954 Dwinnell, Dahlin and Ghormley reviewed fifteen cases under the title of " parosteal (juxtacortical) osteogenic sarcoma," concluding that the tumour was of low-grade malignancy from the start. They found no good evidence that myositis ossificans was implicated, and no evidence of any other pre-existing benign lesion. In spite of the difficulties in establishing histological evidence of malignancy they felt that the clinical behaviour of the tumour justified early amputation.

Lichtenstein (1955), however, regarded these lesions as juxta-cortical tumour-like masses of metaplastic bone or cartilage or both, in which malignant change was uncommon and for which amputation should not be done without convincing pathological proof of malignancy. Although the lesion was analogous to myositis ossificans elsewhere, he conceded a greater liability to malignant change when the situation was parsoteal, with slow and subtle development of one type of " periosteal," " parosteal " or " juxta-cortical " osteogenic sarcoma. In this he followed Jaffe and Selin (1951) who, in describing the more favourable course of their juxta-cortical type of osteogenic sarcoma, thought that this tumour might represent the parosteal counterpart of the malignant form of myositis ossificans.

Fine and Stout (1956) stated that parosteal osteoma, unlike the benign implication of its name, was a malignant tumour, capable of metastasising, and distinguished from soft-tissue osteogenic sarcoma only by its slow progression from histologically benign to malignant tumour and by its attachment to, and involvement of, bone.

The following case is reported because of histological evidence suggesting a benign tumour with sarcomatous change. There was also radiological evidence of malignancy, and abnormal arteries of a type not described in the literature were seen. The histological nature of these is described.

CASE REPORT

A married woman aged thirty-six years developed an ache behind her left knee. Six months later a lump was noticed, but operation was refused because of an impending trip to England. In London, in July 1954, about seven months after the lump had been found, biopsy was performed by Mr H. W. Wright. The histological examination (by Dr L. Woodhouse Price) showed dense fibrous tissue admixed with delicate collagen fibrils and fibroblastic cells (Fig. 1). Dr Price considered that the lesion was essentially fibromatous, and that if it were a fibrosarcoma the degree of malignancy was manifestly extremely low. The patient was first seen in the Hutt Hospital in April 1955, when the ache behind the knee was increasing in severity, especially at night, and was aggravated by heat. She had no other relevant complaints, and the family and past history were irrelevant. On examination a fixed smooth bony mass was palpable in the upper part of the left popliteal fossa, about three inches long and two

inches wide. It extended round the lateral aspect of the femur and was slightly tender proximally. There was no surrounding induration and only-minor restriction of knee flexion. There were no palpable inguinal glands and there was no muscle wasting. The laboratory examinations were normal except that the erythrocyte sedimentation rate was 28 millimetres in the first hour.

Plain radiographs showed a mass of new bone on the cortex of the posterior and lateral aspects of the lower end of the femur. Posteriorly, transradiant areas through the new bone suggested islands of cartilage. In many parts the surface of the new bone was smooth and well defined, but, behind, irregular strands extended into the soft tissues perpendicularly to the shaft. Anteriorly there was some rarefaction of the cortex and the underlying bone. The lung fields were clear.

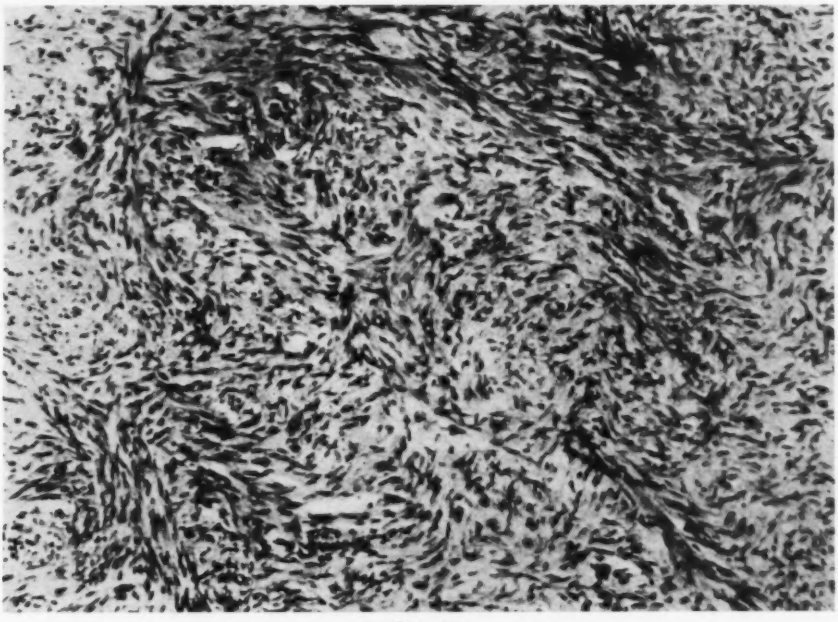

FIG. 1
Section shows dense fibrous tissue admixed with delicate fibrils and fibroblastic cells. Original biopsy in London 1954.

A left femoral arteriograph showed an increased regional circulation with a vascular plexus in and on the tumour at three main points (Figs. 2 and 3). Several arteriovenous shunts could be seen in the arterial phase. There were two pathological arteries with localised constrictions and dilations along their courses, presenting the " bow-tie " appearance (Fig. 4). Final radiological diagnosis was osteochondrosarcoma.

Biopsy specimens were taken at three widely separated points. The first specimen consisted of several portions of white fibrous tissue with attached bony fragments. Sections showed irregular trabeculae of bone with intervening fibrous tissue containing very occasional giant cells. There was no evidence of sarcomatous change. Another specimen consisted of a piece of firm white fibrous tissue measuring $2{\cdot}5 \times 1 \times 0{\cdot}5$ centimetres, one end of which contained a few fragments of bone. The sections showed a mass of dense cellular fibrous tissue with trabeculae of bone. There was one small island of cartilage. The third specimen consisted of a flattened piece of bony tissue measuring $2{\cdot}5 \times 2 \times 0{\cdot}5$ centimetres. The sections

FIG. 2

FIG. 3

Serial arteriographs showing venous filling in the arterial phase at three main points. They are taken at three seconds (Fig. 2) and five seconds (Fig. 3) after the injection of the radio-opaque fluid into the femoral artery. There is increased regional circulation and pathological arteries are outlined.

FIG. 4

Enlarged arteriograph showing the " bow-tie " appearance in the pathological arteries.

showed fibrous tissue involving striated muscle with bone formation in the fibrous areas. The process had involved the adjacent fatty tissue. The sections indicated that this was a fibrous tumour extending into muscle and undergoing ossification. There was no evidence of malignancy. The conclusion was that the tumour was a parosteal osteoma.

FIG. 5
Midline sagittal section of the tumour at the lower end of the femur. The posterior cortical bone is destroyed.

The left leg was amputated two months later through the mid-thigh leaving an eight-inch stump. Sixteen months later the patient was well and there was no evidence of recurrence. The latest follow-up (from Australia) in March 1958 stated that the patient was fit and was eight weeks pregnant.

Examination of the specimen—To enable histological examination of the abnormal arteries demonstrated radiographically, coloured gelatin was injected into the femoral artery, and vessels were dissected out and identified by comparison with radiographs.

Dissections revealed a bony mass on the posterior surface of the lower part of the femur, extending along it proximally for 9·5 centimetres, and almost enveloping the shaft from either side. Proximally there was obvious extension into muscle. On midline sagittal section the growth was predominantly extra-periosteal (Fig. 5). The posterior cortex was intact proximally

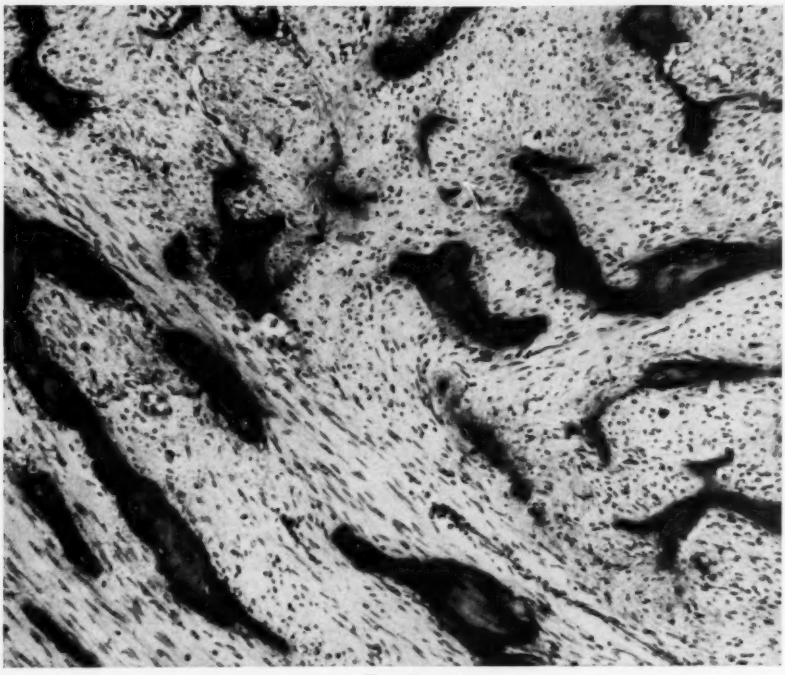

FIG. 6
The typical appearance of the tumour.

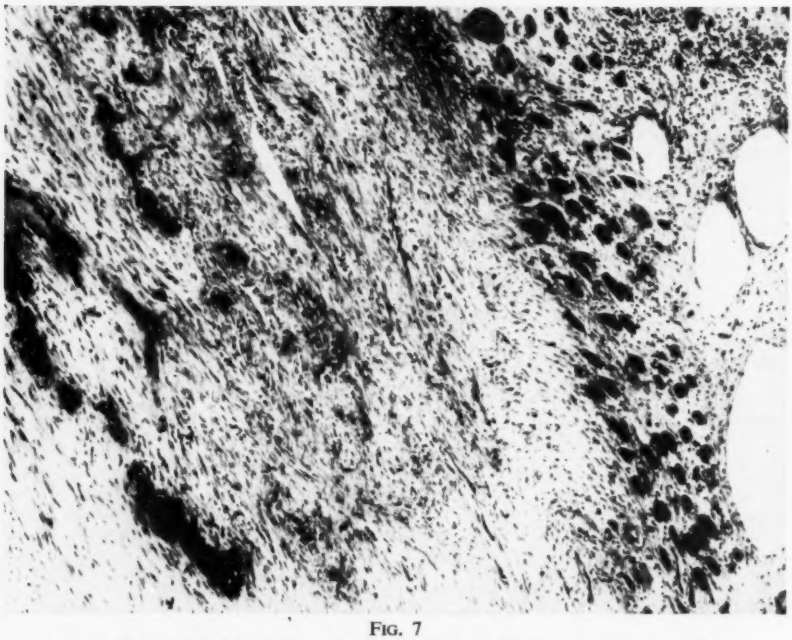

FIG. 7
Part of the proximal end of the tumour, showing infiltration of muscle and fat.

but destroyed below this, yet without much invasion of cancellous bone. In the lateral condyle both anteriorly and laterally the cortex had been invaded.

Microscopically, some variation in histological appearances was seen in different areas. At the proximal end, cells were small and spindle-shaped with oval nuclei of very uniform appearance. Collagen fibres were dense and numerous, and there were many small irregular pieces of rather coarse new bone. Vascular spaces were small and few (Fig. 6). In adjoining areas cells were elongated and of fibroblastic type, more loosely arranged and with less collagen and bone. In still other parts the cell pattern was of herring-bone type, or gave a watered silk appearance, and here bone formation was almost absent. Only one or two very small pieces

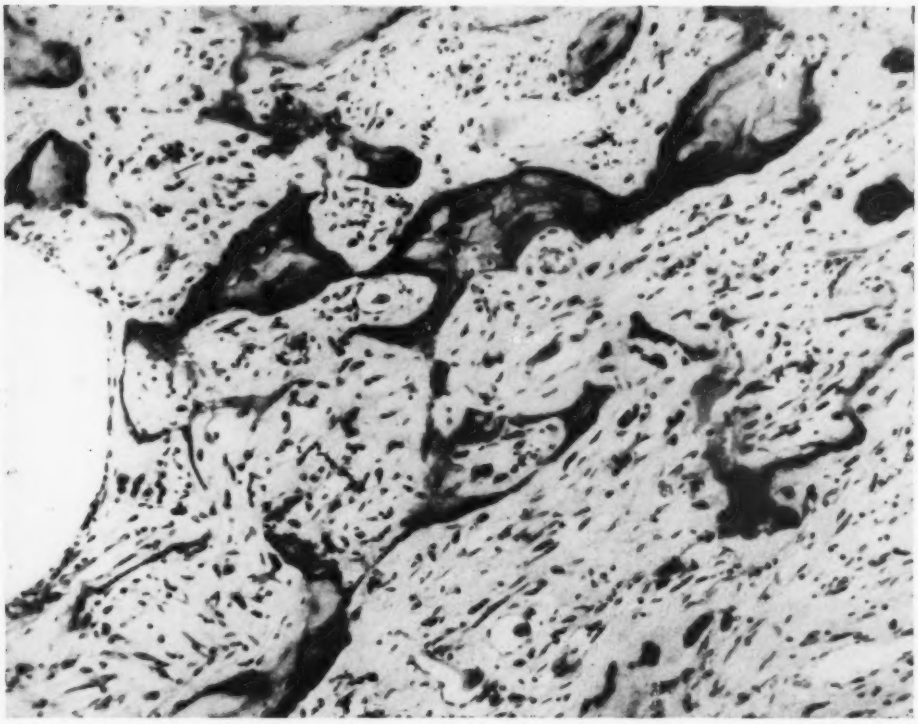

FIG. 8

Section is from the area with bone invasion. Numerous large cells with hyperchromatic nuclei of irregular shape are lying in disorderly fashion. Part of a large vascular space is present.

of cartilage were seen in the entire specimen, but bone formation was in general abundant. At the periphery there was direct infiltration of muscle (Fig. 7) and fat. Although benign in appearance in its greater part, the tumour was of different histological character in the areas where there was destruction of cortex and invasion of bone. Here (Fig. 8) the cells were larger and of variable shape, with scattered bizarre hyperchromatic single or multinucleated cells of malignant appearance. The stroma was loose and myxomatous, and bone formation was much less orderly. Very large vascular channels were seen, and appeared as endothelial-lined spaces without organised walls; apart from their size and frequency they differed in no way from the vascular spaces elsewhere in the growth.

Sections of the " bow-tie " artery, followed serially (at every 100μ), showed localised thickening of the media, projecting into the lumen. The media appeared loose and oedematous

or myxomatous with a slightly basophilic tinge to the matrix. The internal elastic lamina could be followed, at least in part, around the periphery of the invaginating mass. No inflammatory reaction or tumour invasion was seen (Fig. 9).

FIG. 9
Low-power view of the " bow-tie " artery which shows the thickening of the media responsible for the constriction of the lumen.

DISCUSSION

The abnormal arteries demonstrated by the arteriograph have not before been noted in the literature. Their histological counterpart appeared as focal thickenings within the media, but they are not considered in any way specific.

Inclan (1942) and Mucchi and Columella (1951) considered that the demonstration of filled veins in the arterial phase of injection indicated malignancy. Dos Santos (1950) regarded the degree of malignancy as directly proportional to the number of arteriovenous shunts. In this case the finding of three shunts could have enabled a correct prediction of a tumour of low malignancy.

An attempt was made to see if histological appearances of malignancy were to be found in those areas where the large shunt veins were seen emerging. No such correlation could be made, but in the areas examined very large veins could be seen running in benign tumour tissue. Presumably the shunts occur at some distance from the points where confluent veins attain a size capable of radiographic demonstration.

There did appear to be good correlation between histological differentiation and the number and size of vascular channels, which in benign areas were small and few, but in malignant areas were large and numerous. But as vessels almost equally large have been seen in myositis ossificans, this finding must be regarded as non-specific. No direct arteriovenous communications were identified.

Apart from those areas with invasion of bone the appearances most closely resembled those of ossifying fibroma, a term, indeed, which was used by Copeland (1951) as a designation for the tumour. No evidence can be brought to show whether or not myositis ossificans was

an antecedent lesion in this case and there seems to be no necessity to infer its participation. Certainly the histological appearances at the time of amputation were those of a neoplasm infiltrating muscle, fat and bone rather than any reparative type of fibrosis. The fact that only a small area with the histological criteria of malignancy could be found in a large tumour of two years' duration suggests that malignancy was of relatively recent development. It must be conceded, however, that the histological evidence of malignancy seen here is not by itself sufficient to infer clinical behaviour with accuracy. Rather, accumulated clinical experience with this type of tumour must be used to indicate what significance attaches to the microscopic picture. The degree of malignancy propounded by Dwinnell *et al.* (*loc. cit.*) is not supported by the clinical experience of Lichtenstein (*loc. cit.*) and for an accurate settling of these differences further experience must be awaited. In the present case, the biopsy material was regarded as benign, and amputation was done because of the radiological findings and because local removal was impractical.

The radiological diagnosis of malignancy necessitates the assumption that vascular shunts are a reliable criterion that may be applied to any growth. However, this is a relatively new approach and its degree of accuracy is not yet known. Within our own experience it would at least appear to have some limitation and require careful evaluation. Other reports of arteriography in this tumour are not available. In the most recent publications by Stevens, Pugh and Dahlin (1957) and that by Sammons, Sarkisian and Krepela (1958) no arteriographs are included.

SUMMARY

1. A case of parosteal osteoma with histologically low-grade sarcomatous areas is described.
2. Arteriography revealed abnormal arteries, the histological appearances of which are described.
3. Vascular shunts indicative of low-grade malignancy were also seen.
4. Reasons are given for accepting the view that this lesion is a tumour, originally benign, but liable to the development of low-grade malignancy.

We wish to thank Mr H. W. Wright and Dr Woodhouse Price for the histological slide of the biopsy done in London and for permission to use Dr Price's report. We also thank Dr H. A. Sissons and Mr G. M. Goodson for their constructive criticism of this paper and Dr A. C. Begg, who confirmed our radiological impression that this was a malignant bone tumour. Mr R. B. Sparke made reproductions of the radiographs and was responsible for the photomicrographs. Mr Philip Wrightson was responsible for the arteriograph and for the initial care of this patient.

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BONE SARCOMA IN PAGET'S DISEASE

Report of a Case with Long Survival

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The prognosis in sarcomata secondary to Paget's disease is distinctly bad, and we have found only one five-year survival (Sherman and Soong 1954) and six two-year survivals reported in the English literature (Coley and Sharp 1931; Hansen 1942; Mercer and Duthie 1955; Porretta, Dahlin and Janes 1957; Platt 1947). Professor Dorothy S. Russell tells us that one of H. Osmond-Clarke's patients (Case 5, 1949), in whom a seemingly highly malignant tibial tumour complicated Paget's disease, was still alive without sign of recurrence ten years after amputation.

The following is a case report of a man who lived for almost eight years after local excision of a sarcoma of a humerus which was the site of Paget's disease.

CASE REPORT

In 1918, when the patient was twenty-four years old, he noticed that his right leg was becoming bowed and was occasionally painful. The deformity slowly increased and when

FIG. 1
Humerus showing Paget's disease with an osteolytic lesion in the mid-shaft.

he was thirty-eight years old his left leg began to bow and he also noticed that his head was becoming larger. In June 1940, at the age of forty-six, his right leg " gave way " and he was unable to stand on it. He was admitted next day to the Massachusetts General Hospital and

was found to have a transverse fracture of the tibia and fibula, the bones being affected by Paget's disease. Radiographs of the skull, pelvis and left femur also showed evidence of Paget's disease. The fracture was treated by open reduction and internal fixation with a metal plate and screws. Sepsis, which at first appeared to be superficial, later developed into chronic osteomyelitis, requiring an above-knee amputation in February 1948. No evidence of tumour was found in the amputated limb. After the operation partial necrosis of the skin flaps developed.

While in the hospital in June 1948 he called attention to a painless swelling of his right arm which he had discovered two weeks before. On examination, a hard, immovable, irregular, non-tender mass measuring three inches by three inches was found arising from the antero-medial aspect of the humerus. Radiographs (Fig. 1) showed evidence of Paget's

FIG. 2

FIG. 3

Figure 2—Radiograph six weeks after operation showing loss of fixation between fibular graft and upper humerus. Figure 3—Radiograph four years after operation showing pseudarthrosis.

disease in the humerus, and there was an osteolytic defect in its middle third involving about half of the diameter of the shaft. The chest film was negative.

Operation—The lesion was diagnosed clinically as an osteogenic sarcoma and it was decided to attempt local resection without preliminary biopsy. At operation the tumour was found to have invaded only the brachialis muscle. The tumour, brachialis muscle and six inches of the humerus were excised, allowing approximately a two-inch margin of almost normal bone on either end of the tumour mass. The gap was bridged by a bone graft consisting of eight inches of the left fibula, fixed to the humerus with one screw proximally and two screws distally. Histological examination of the specimen confirmed the diagnosis of osteogenic sarcoma.

Progress—Difficulty was encountered in controlling the position of the arm in a spica: bone contact between the graft and upper humerus was lost (Fig. 2), and a frank pseudarthrosis developed later (Fig. 3). Although great care was taken in protecting the nerve trunks a radial

nerve palsy was noted after operation. Severe arthritic changes in the remaining leg and the impaired function of the arm confined him to a wheel-chair. In spite of the pseudarthrosis

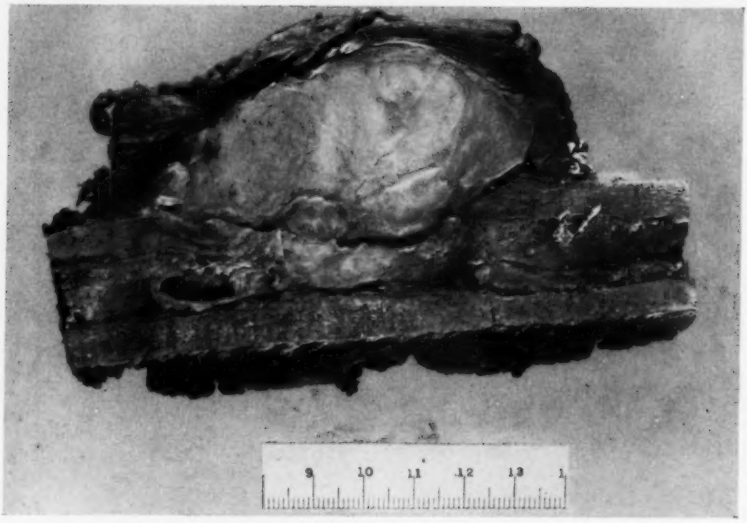

FIG. 4
Photograph of specimen showing thickening of cortex and sarcoma invading brachialis muscle. (Scale in centimetres.)

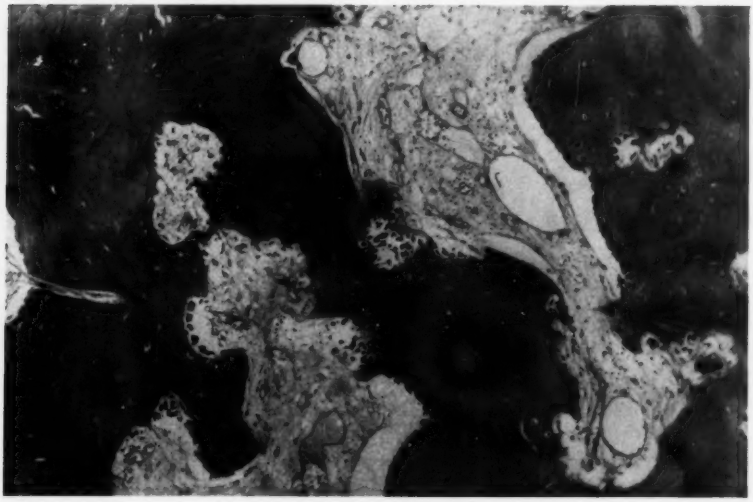

FIG. 5
Section of specimen taken from resected margin of humerus showing active Paget's disease of bone. (Haematoxylin and eosin, ×125.)

and the radial nerve palsy, function of the hand and of the extremity as a whole was so good that further surgery was deemed inadvisable. His general health remained good until February 1956 when he was readmitted to the Massachusetts General Hospital with acute urinary retention. After decompression of the bladder he remained very ill for several weeks with a

labile electrolyte balance, but recovered and was discharged in March 1956. He died in April 1956 of cardiac failure seven years and ten months after resection of the sarcoma.

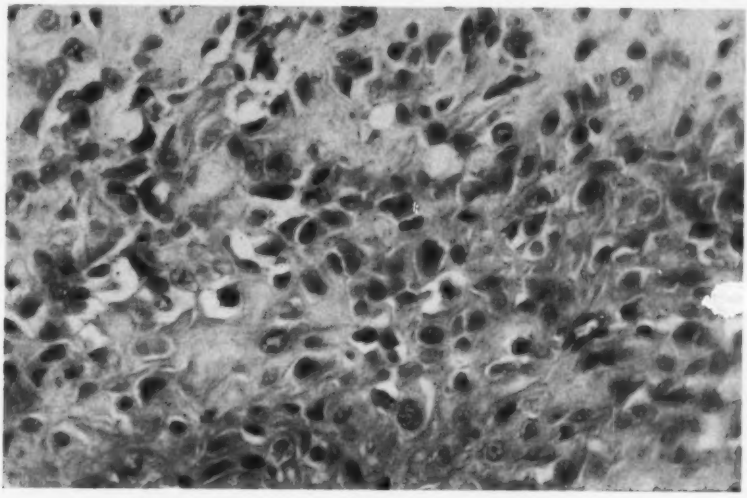

FIG. 6
Section of tumour showing plump tumour cells with abundant mitotic figures separated by amorphous intercellular substance. (Haematoxylin and eosin, ×450.)

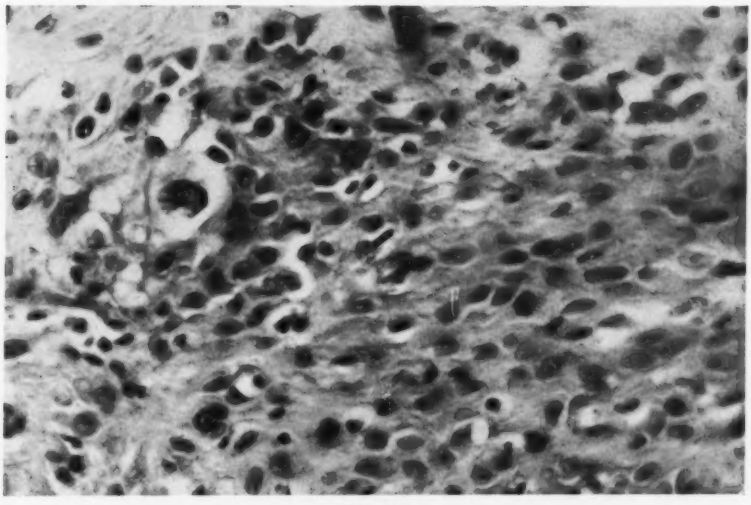

FIG. 7
Section of tumour showing pleomorphic cells with more scanty intercellular substance than in Figure 6. The intercellular substance contains abundant collagen. (Haematoxylin and eosin, ×450.)

While he was in the hospital in 1956 clinical and radiological examination revealed no evidence of local recurrence or pulmonary metastases. No necropsy was secured.

Pathology of the specimen—The specimen consisted of part of the humerus fourteen centimetres long (Fig. 4). A firm fibrous mass had destroyed part of the cortex, producing an elliptical

defect six centimetres long and four centimetres wide. It had penetrated to the opposite cortex but there was no extension along the medullary cavity. The tumour was ovoid, with its greatest dimension where it had invaded the brachialis muscle and, though well circumscribed, did not have a capsule. The cortex of the humerus was irregularly thickened at the part adjacent to the tumour.

Microscopically, the cortex from the resected margin of the specimen showed active Paget's disease with numerous osteoblasts and osteoclasts and areolar fibrosis of the intertrabecular spaces (Fig. 5). Early conversion of the cortex into a mosaic of angular lamellar systems was present. The tumour had invaded brachialis muscle bundles, but no invasion of blood vessels was seen. Multiple sections of the tumour showed a sarcoma with fairly numerous and often atypical mitotic figures. Many areas were composed of plump tumour cells separated by a pale pink intercellular substance resembling osteoid tissue (Fig. 6). Elsewhere, whorled masses of elongated tumour cells were intermixed with abundant collagen (Fig. 7). Transitions between these fields were frequent, and collagen bundles could be followed into the more amorphous pink substance. No new bone trabeculae or calcification were seen.

DISCUSSION

This tumour was originally diagnosed on histological examination as an osteogenic sarcoma, but a review of the sections reveals no true osteoid or bone. As we believe that osteogenic sarcoma cannot be diagnosed in the absence of either osteoid or bone, we consider that this tumour is a fibrosarcoma. Lichtenstein (1952) states that fibrosarcoma occurring in Paget's disease " is not unusual " and it seems likely that some of the sarcomata of Paget's disease that have been reported as osteogenic sarcomata are, in fact, fibrosarcomata. This finding does not detract from the rarity of the long survival after local excision.

The early age of onset of Paget's disease in this man and the lack of pain in his tumour are both of interest and may have a bearing on his survival.

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LONG SURVIVAL AFTER AMPUTATION FOR PAGET'S SARCOMA OF BONE

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Malignant tumours arising in bones that are the seat of Paget's disease have a well deserved reputation for extreme malignancy. It seems therefore of some importance to report cases with long survival, in order to dispel in at least a small part the view that treatment is purely palliative. We know of three cases in which survival has been sufficiently prolonged to justify the presumption of cure. Two of these are previously reported cases in which the authors concerned have been good enough to give us details of later history; the third is our own.

Sir Harry Platt has given us details of two cases in his series (Platt 1947). In one of these (Platt's case 5), that of a man of sixty-seven with a polymorphic-cell sarcoma of the shaft of the humerus, the patient had survived two years when reported, and has been quoted (Lennox 1949, Lake 1951) as possibly cured. However, this man died five years after the discovery of the tumour, with signs of metastasis in the lumbar spine and probably elsewhere; there was no necropsy. A second patient (Platt's case 6) treated in 1946 and too recent for follow-up at the time of the original report is, on the other hand, now (1957) alive and well eleven years after operation. In that case the tumour was a spindle-cell sarcoma, arising endosteally in a humerus, the seat of predominantly osteoporotic Paget's disease, and treatment was by disarticulation at the shoulder.

The second surviving patient is one reported by Russell (1949), with a malignant osteoclastoma arising in Paget's disease. The patient (Russell's case 5), a woman of fifty-nine, had a tumour of the tibia treated by mid-thigh amputation. At the time of Russell's report she had survived for nineteen months, and the patient was still alive when the case was included in those discussed at a slide seminar on bone tumours held during the Belfast meeting of the Pathological Society in 1953. Professor Russell has now informed us that the woman is still alive and well, over ten years after amputation. Lichtenstein (1949), and Dr H. J. Jaffe (in discussion at the seminar just mentioned), have expressed doubts as to the diagnosis in this case, regarding it as a pleomorphic osteosarcoma. Taking Russell's series as a whole, however, it is clear that she has considerable justification for her view that some Paget's sarcomata may first appear as osteoclastomata. One of us has seen some of the sections in this case and has come to the conclusion that in so anaplastic and diversified a tumour the probability of osteoclastomatous origin could at the very least not be excluded. In any case, it is clear from the other examples in Russell's series that tumours of this type are ordinarily frankly malignant, and that we need have no hesitation in including this case in the present series.

CASE REPORT

A man aged sixty-four first came under observation in 1947 with a fracture of the right tibia. This bone, the right femur and the skull presented typical radiographic appearances of Paget's disease. The fracture united soundly within three months.

A year later the patient sustained a second fracture, this time through the lowest third of the right femur. Radiographs at this time did not suggest the presence of a tumour at the fracture site (Fig. 1). Union was satisfactory and full function was regained within six months. Almost a year later, in July 1949, the patient reported again complaining of pain at the site of the old fracture of the femur. On clinical examination, some local tenderness and increased

soft-tissue firmness were found over the lateral aspect of the lowest third of the femur. Radiographs showed the fracture soundly united, but there was loss of cortical definition and some decreased bone density on the lateral aspect of the femur at the site of tenderness (Fig. 2). A week later a firm tender mass was palpable at the same site, four inches above the knee. An open biopsy was performed and a solid vascular tumour was found. Mr J. Tulloch Brown performed an amputation through the right thigh, three inches distal to the lesser trochanter.

The patient's progress after operation was excellent and he has been seen regularly since his discharge from hospital. He was last examined six years and seven months after the operation. He was then aged seventy-three, had no complaints, and walked well on an

FIG. 1

Radiographs of right femur at the time of the pathological fracture. Typical changes of Paget's disease are present.

artificial limb, supplied four years previously. There was no clinical evidence of local or distant recurrence of the tumour. Having moved to another district, the patient reported by letter, seven and three-quarter years after the operation, that he was still in good health and as active as he had been when last seen.

Pathology—The original biopsy (Fig. 3) showed an unmistakable sarcoma. It is predominantly spindle-cell in type, with marked nuclear pleomorphism and numerous mitoses. There are a few small tumour giant cells but no osteoclasts. There is no trace of osteoid tissue or of cartilage.

The description now available of the amputation specimen is, unfortunately, not very full. " Transverse sections of the femur were cut and a sarcoma was seen involving the femur to within two inches of the amputation. This was white in colour and fleshy looking, and spread out into the surrounding tissues. The medullary cavity is especially invaded."

To obtain the transverse sections just mentioned the specimen was frozen, and the histology is in consequence very poor. However, it is sufficient to make it clear that the biopsy specimen was a representative sample, the tumour being of uniform structure throughout. The actual bone trabeculae are well preserved, and the diagnosis of Paget's disease is confirmed (Fig. 4).

DISCUSSION

Bone sarcoma in Paget's disease has been the subject of several reviews (Coley and Sharp 1931, Summey and Pressly 1946, Lennox 1949, Lake 1951), and we wish only to comment on two statistical aspects.

FIG. 2

Radiographs of right femur ten months later. The fracture is soundly healed but there is an area of bone destruction on the lateral side of the lowest third of the shaft.

In the first place, the relative frequency of the disease seems to have increased since Coley and Sharp, using the material of the American Bone Tumour Registry in 1931, reported that 28 per cent (twenty of seventy-one cases) of bone sarcomata in men over fifty were associated with Paget's disease. Price (1955), using English cases, gave a substantially higher figure for the same age group (47 per cent for men and 59 per cent for women). Our own material, though small, gives an even higher proportion; in a series of fully studied bone tumours collected jointly by our two departments in the last four years, Paget's sarcomata account for four of six bone sarcomata occurring in men over fifty, and in six of nine men over thirty. It may be that these figures represent a geographical and secular trend, that Paget's sarcoma is commoner in Britain than in America, or commoner now than in 1931. It seems, however, that improved diagnosis is the most likely cause. Paget's disease is now diagnosed more frequently by the radiologists, and histologists are now able to reject a number of

lesions that must formerly have been included among the osteosarcomata. Since most of the spurious sarcomata occur in patients without Paget's disease, both factors will tend to raise the relative frequency of Paget's sarcomata.

It is worth also considering the reasons for the poor prognosis of Paget's sarcomata. The uniformly black outlook postulated by all the writers on the subject with which we are acquainted has not been greatly mitigated by the cases we have reported. It is not possible to determine what cure rate they represent. By application of Price's percentages to the Registrar-General's figures for deaths from bone tumours and Paget's disease in England

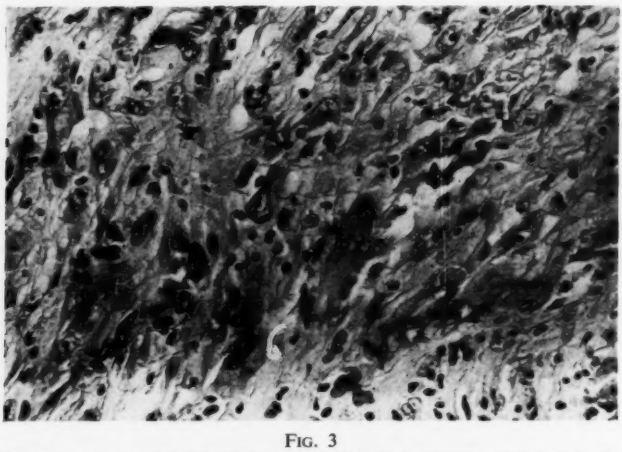

FIG. 3
Section from biopsy specimen. A spindle-cell sarcoma with moderate nuclear pleomorphism. (H. and E., ×250.)

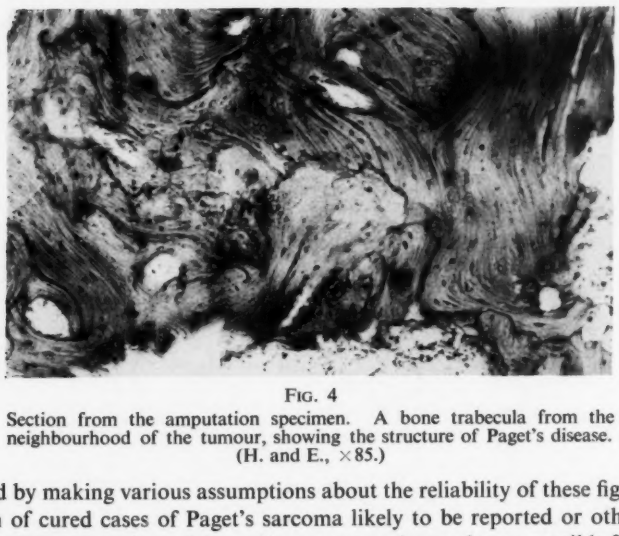

FIG. 4
Section from the amputation specimen. A bone trabecula from the neighbourhood of the tumour, showing the structure of Paget's disease. (H. and E., ×85.)

and Wales, and by making various assumptions about the reliability of these figures and about the proportion of cured cases of Paget's sarcoma likely to be reported or otherwise become known to us, we have arrived at a figure of 1 per cent as the maximum possible for the cure rate in this disease.

Speculative though this figure is, few people will claim that it is too large. It may, therefore, legitimately be compared with the cure rate of 15 per cent for osteosarcomata

in general (the figure is that of MacDonald and Budd (1943) but most estimates are in this neighbourhood). Of factors that may contribute to this very striking difference, the following seem worth mentioning.

Age of patient—This may incline some surgeons against major surgery, and, by increasing the likelihood of intercurrent deaths, reduce the crude five-year survival rate.

Site of tumour—Cure in osteosarcomata is practically limited to limb tumours suitable for amputation. In non-Paget osteosarcomata over 90 per cent occur in the limbs (Geschickter and Copeland 1949, from their Tables 17, 18, 21 and 22). In Paget's sarcoma 40 per cent of the cases occur in such sites as skull, vertebrae and ilium (Summey and Pressly 1946).

Multicentric origin, much commoner in Paget's sarcomata than in other osteosarcomata, obviously affects the prognosis unfavourably.

Histological misdiagnosis—It is probable that there are fewer misdiagnoses of malignancy in Paget's sarcoma than in other bone tumours.

Vascularity—It may well be that the extreme vascularity of bones affected by Paget's disease accelerates the metastasis of tumours arising in them.

Late diagnosis of malignant change in a bone affected by Paget's disease is common. This is due to difficulty in the interpretation of symptoms, signs and radiographs of early tumour in bones which are already the seat of disease.

It can only be a matter of speculation whether the factors enumerated above account for the poor prognosis of Paget's sarcoma, or whether the tumours possess some intrinsic malignancy denied to other osteosarcomata. Histological evidence for the latter assumption is lacking: it has not been established that Paget's sarcomata, taken as a whole, differ histologically from other osteosarcomata, and in the absence of any satisfactory system of grading, the assessment of the significance of any such differences that were established would be difficult.

Whatever the cause of the poor prognosis, we regard it as a matter for encouragement to have been able to demonstrate that it is not quite so unrelievedly black as it has been painted, and that limb amputation in some cases of Paget's sarcoma offers the prospect of an occasional cure. Most patients with Paget's sarcoma die within two years at most and the five-year survival of the patient in Platt's case 5 is exceptional. It seems justifiable, therefore, to claim all three of the cases we have mentioned, already surviving seven years or more, as cures.

SUMMARY

A patient with Paget's sarcoma of the femur, alive and well seven years after amputation, is reported. Long survival in two previously reported cases is also mentioned.

Our thanks are due to Mr J. Tulloch Brown for permission to publish this case, and to the chiefs of our respective departments, Mr Roland Barnes and Professor D. F. Cappell. We are also most grateful to Professor Dorothy Russell and Sir Harry Platt for the details of their cases.

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AN APPARATUS FOR USE IN NAILING OF THE FEMORAL NECK

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In the treatment of fracture of the neck of the femur by Smith-Petersen's operation, the quicker this procedure can be performed efficiently the better it is for the patient. We have found the apparatus described below, which was devised by one of us (K. H. P.), to be of the greatest value in achieving this end.

DESCRIPTION OF APPARATUS

The apparatus is made of wood. It consists of three parts: the base, the cassette holder and the leg rest (Figs. 1 and 2).

The base or platform rests on the surface of the standard operation table. On its upper surface are two transverse grooves (Fig. 2). These grooves are sited 5½ inches and 7 inches respectively from the foot end of the base. Fixed to the distal or foot end of this upper surface is a strong transverse strut, to which the leg piece is attached by hinges.

The construction of the cassette holder is illustrated in Figures 1 and 2. The perineal upright is fixed to its upper surface by four screws. On the lower surface of the cassette holder, near the foot end, there is a transverse rail, designed to fit accurately into one or other of the grooves on the upper surface of the base. When the apparatus is assembled the cassette holder rests on the base. The transverse rail, lying in one of the grooves on the base, prevents movement between the two components in the longitudinal direction, but the cassette holder is free to slide upon the base in a transverse direction. This allows the desired degree of abduction of the legs to be attained.

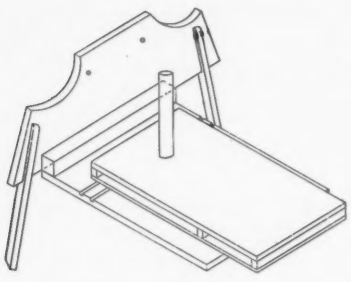

FIG. 1

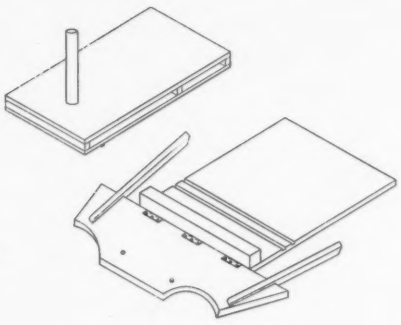

FIG. 2

Figure 1—Drawing of the apparatus assembled. Figure 2—The apparatus dismantled to show the component parts.

The leg rest consists of a main transverse component and two projecting struts (Figs. 1 and 2). The main part is a trapezium, the smaller parallel side being uppermost when the apparatus is assembled. It is attached to the base by hinges. The upper and outer angles are removed and notches are fashioned which support the back of the flexed knees when the patient is in position. The projecting struts are attached near each side to the headward surface of the main part and project below it, diverging 10 degrees from the vertical. The angle at which these struts diverge is designed so that when the patient is in position the neck of the femur is horizontal and is parallel with the floor. Near the upper margin of the main piece a rope handle is attached, for carrying.

When in use the assembled apparatus is attached to the top of the operation table by two clamps, which exert pressure between the lower part of the cassette holder and the standard table rails. These clamps do not interfere with the insertion of the x-ray cassette.

METHOD OF USE

The lower hinged end of the operation table is removed and the apparatus is placed in position so that the leg rest is hinged over the end of the table (Figs. 3 and 4). The cassette holder is then placed in position so that the wooden rail on its under surface is fitted into either the proximal or distal groove on the upper surface of the base. For patients with relatively short

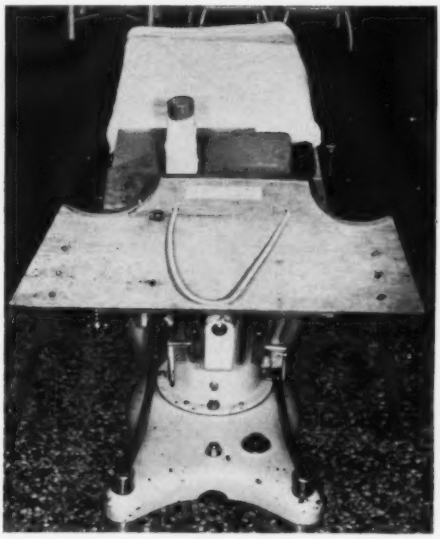

FIG. 3

FIG. 4

Figure 3—The apparatus in position on the operation table, for nailing of the right femoral neck. Figure 4—To show the position of the patient on the apparatus.

legs the distal groove will be used and for those with longer legs the proximal groove. If necessary additional padding between the perineal post and the perineum or between the back of the knees and knee rests may be found useful.

When the right femoral neck is to be nailed the right edge of the cassette holder is placed flush with the right border of the base, which should be flush with the right side of the table. This position ensures the correct amount of abduction of the legs when the patient is placed on the apparatus. The reverse position is adopted for fractures of the left femur. A large square of polythene padding is placed on the upper surface of the cassette holder to protect the patient's sacral area, and the leg supports are similarly well padded. The importance of proper protection of these patients by adequate padding and gentle handling cannot be overstressed.

The anaesthetised patient is placed on the apparatus so that the perineal pole rests snugly against the groin. The sound leg is flexed over the corresponding notch of the leg rest, and bandaged to the projecting strut as it lies. The fracture is reduced by manipulation, and the injured limb is bandaged to the projecting leg piece on that side. With the patient supported thus it will be found that reduction of the fracture is maintained, and the surgeon may proceed with the operation in the usual way.

We wish to thank Mrs A. Westhead, of Ham Green Hospital, Bristol, for the drawings, and the photographic department of the Bristol Royal Infirmary for their generous and painstaking assistance.

THE RESTORATION OF ARTICULAR SURFACES AFTER JOINT EXCISION

An Experimental Study with Cartilage Implants

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It is now well recognised that many different complex factors are involved in the problems of joint reconstruction. This paper attempts to deal with only one of these factors, the mechanism of the formation of a cartilaginous surface covering the bone ends within the joint.

No foreign material has yet proved permanently satisfactory as an articular surface, when subjected to the stress and strain inherent in a functioning, weight-bearing joint. We think that it is unlikely that there will be any substantial advance in joint reconstruction while attention is confined to the replacement of joint surfaces by inert foreign substances. Future success will surely depend on the development of a method of controlled stimulation of the production of new articular cartilage by the host tissues after reconstructive procedures.

This kind of process is seen in other tissues, such as bone, nerve and blood vessels. In the reconstitution of these tissues, transplants do not themselves proliferate to replace deficiencies. Rather do they behave as a matrix into which the specific cells of the host grow. This is typically seen in a peripheral nerve transplant, where the host Schwann cells proliferate as the bands of Büngner along the mechanical channels formed by the endoneural tubes of the transplant.

There is a possibility that cartilage implanted into a site of potential cartilage formation (such as a joint) may act in a somewhat similar way, determining the path of growth of host cartilage cells and moulding the shape of the resulting cartilage mass, while the implant itself undergoes gradual dissolution.

With regard to the formation of new cartilage in joints, Gibson and Williams (1951) demonstrated that under normal conditions of weight bearing and movement in the hip joint fibrous tissue is converted into fibrocartilage on each side of a Smith-Petersen Vitallium cup. The implantation of such foreign materials into joints produces poor late results. Moore (1948) used cartilage cup arthroplasty in ununited fractures of the femoral neck. Independently we conceived the idea of using cartilage implants, which are by their nature only temporary. Here we have to guide us, first, the experiences already outlined, which have been gained from the use of other tissue transplants. In the second place, Peer (1939) showed that only cartilage from the host's own body (autogenous tissue) remains for any length of time at the site of transplantation. Cartilage from other individuals (homogenous) or other animals (heterogenous) is removed at a speed dependent on the intensity of the host antigen-antibody reaction (Craigmyle 1955).

It is reasonable, therefore, to postulate that a cartilage cap inserted into a joint over the rawed end of a long bone will serve as a smooth weight-bearing surface and will, at the same time, mould the new joint surface that is being formed beneath it. Probably the implant will be absorbed gradually, but there may well be sufficient time for the production by the host tissues of a new articular surface of fibrocartilage or hyaline cartilage beneath it.

To test this hypothesis we have undertaken a controlled series of experiments on the elbow joint in monkeys, in which by repeated biopsies a serial picture was built up of the progressive changes that occur after such procedures as excision of the radial head and implantation of dead cartilage.

These experiments were designed to answer the following questions: 1) What is the precise mechanism of healing of a raw bony surface in a joint? What cells are involved? Where do

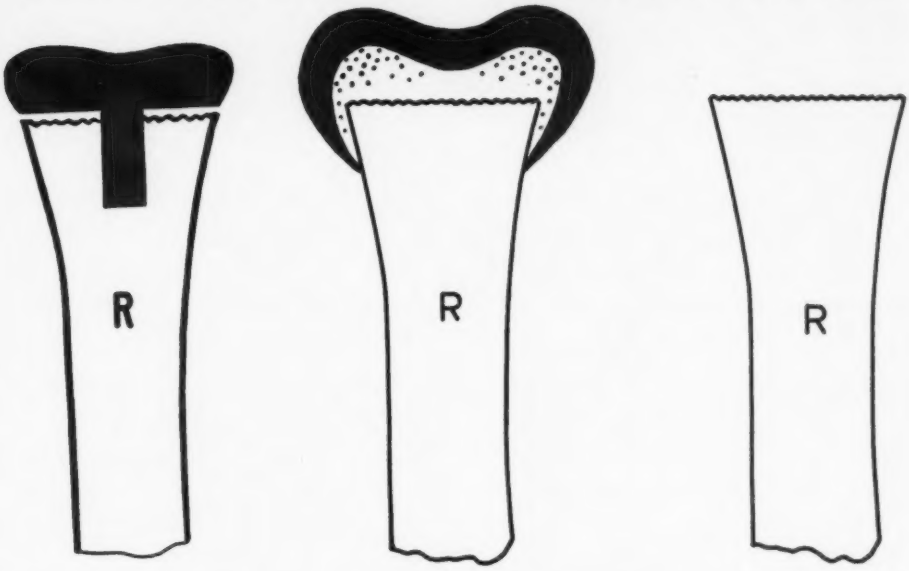

FIG. 1

Diagrams to illustrate the types of experiment performed. *Left*—Head of radius excised and replaced by heterotransplant of whale cartilage pegged into medullary canal. *Middle*—Implant of fixed autogenous or homogenous cartilage. Stippling represents adherent transplanted bone. *Right*—Simple excision of head of radius without cartilage implant.

they originate? 2) Does the introduction of a dead cartilage implant over the raw bone end affect in any way the final constitution of the new articular surface? 3) What is the final fate of such an implant?

METHODS

The radio-humeral joint of the common vervet monkey was chosen for our experiments. In this primate the joint is subjected to but slight strains imposed by weight bearing and traction during quadrupedal and brachiating progression. Its main function resembles that of the same joint in man during fine and prehensile movements of the hand (pronation-supination, and flexion-extension, at the radio-capitular articulation).

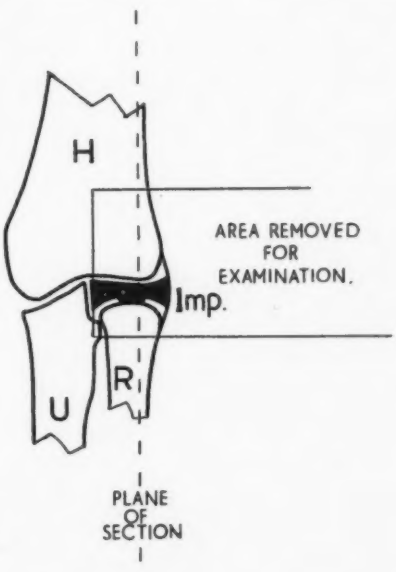

FIG. 2

Diagram to illustrate the tissue removed from the elbow joint for histological examination. H = lower end of humerus; U = ulna; R = radius; Imp. = implant.

A standard technique of operation, post-operative care, biopsy and histology was used in twenty-nine experiments. Under nembutal and ether anaesthesia the radio-humeral joint was exposed through a short lateral incision. The radial head was excised (distal to the epiphysial line in younger animals), together with sufficient bone of the radial neck to make room for the cartilage implant.

The following types of cartilage implant were placed in the joints. 1) A mushroom-shaped implant of preserved whale cartilage (heterotransplant). This was pegged into the radial medullary canal (Fig. 1, *left*). 2) An implant of fixed cartilage in the form of a cap from the contralateral radial head. This was decalcified in acid and as much bone as possible was removed (fixed autotransplant). This fitted neatly over the rawed radial head (Fig. 1, *middle*). 3) A similar implant of fixed cartilage from another monkey (fixed homotransplant) (Fig. 1, *middle*). 4) No implant (Fig. 1, *right*).

After the operation a plaster was applied from upper arm to wrist, with the elbow at a right angle, and left for three weeks. After removal of the plaster the usefulness and range of

FIG. 3

Low-power view showing encapsulation and invasion by fibroblasts of whale cartilage implant. Subjacent to the implant there is a gradual change from fibroblasts to chondrocytes and cartilage matrix which in turn is undergoing endochondral ossification at the radial tip. (×60.) (Whale cartilage implant 1 month.)

movements of the arm were carefully observed. Joints were examined at intervals from one month to two years after operation. The capitulum of the humerus and the upper end of the radius were removed *en bloc* for microscopic examination (Fig. 2). After formol fixation, decalcification and paraffin embedding, longitudinal sections through the entire joint were cut and stained for general histology by haematoxylin and eosin and Masson-Goldner techniques. Certain selected sections were stained by the periodic acid Schiff reaction, the Feulgen reaction and Wilder's reticulin stain. In this way a comprehensive picture was built up of the macroscopic and microscopic anatomy of the whole of each joint.

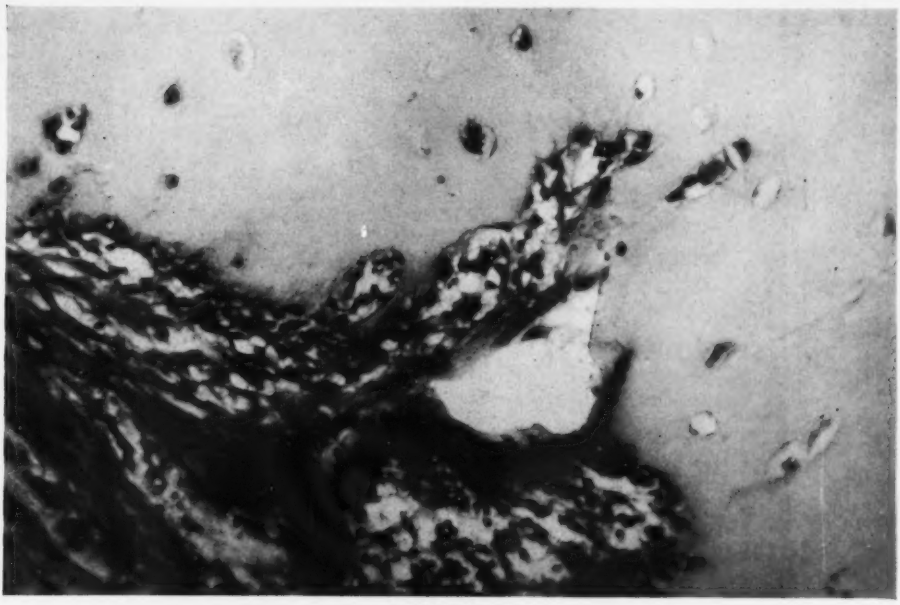

FIG. 4

Invasion of the whale cartilage and destruction of its matrix by fibroblasts and macrophages. Encapsulation by collagen fibres. (×250.) (Whale cartilage implant 4 months.)

FIG. 5

Fibrocartilage at the site of implantation capping the radial tip. Hyaline cartilage collar growing centripetally from the periosteum can be seen in the lower left part of the picture. This is undergoing endochondral ossification. Immediately above it is a bursa-like space lying between it and the site of implantation. (×14.) (Whale cartilage implant 6 months.)

RESULTS

Movement—All the monkeys soon learned to move about their cages with remarkable agility. Within a few days of removal of the plaster all climbed, swung and otherwise behaved in a normal way. In twenty-one joints movements were full, and in eight slightly restricted.

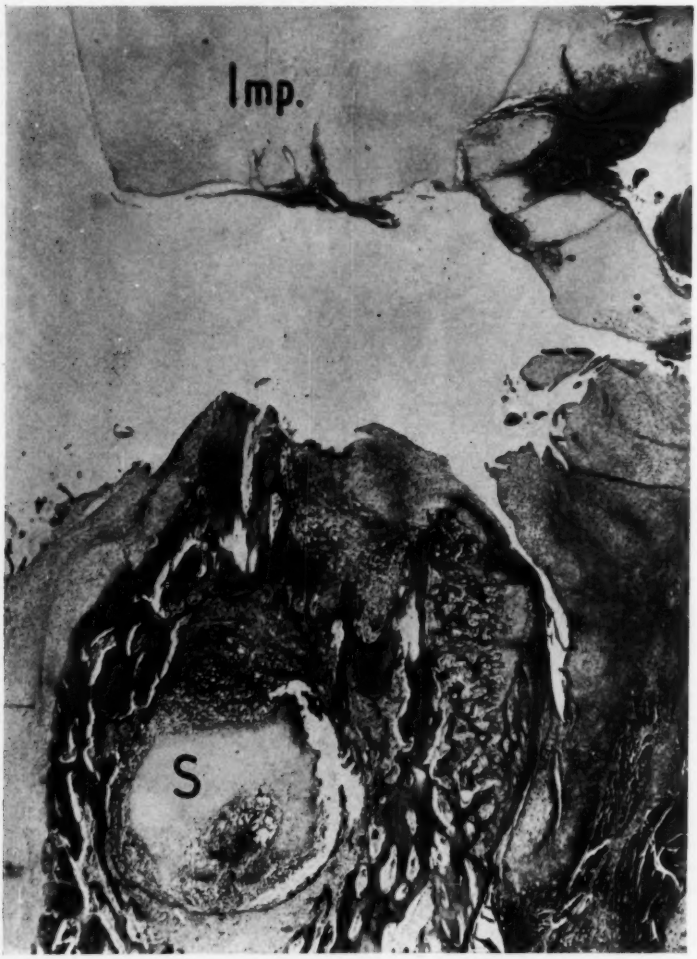

FIG. 6

The end of the radius showing centripetal growth of periosteogenic fibroblasts and cartilage. There is much osteoclastic activity in the projecting spicule. The stem of the implant (S) is seen in the medullary canal. The implant has been artificially separated in preparation from the radial tip on to which it abutted. (×3·5.) (Whale cartilage implant 1 month.)

HISTOLOGICAL STUDIES

Whale cartilage heterotransplants (biopsy performed after 1, 2, 3, 4, 5, 6, 6, 9, 14 and 23 months). *The implant*—This was progressively invaded by cells and fibres. Wilder's stain showed precollagen fibre infiltration together with a mass of invading fibroblasts and macrophages.

During the period studied the implant became transformed into a collagenous mass (Figs. 3 and 4). At 1 *month* the implant was diminished in volume by peripheral cell infiltration. At 2 *months* about half the implant tissue was still present. At 3 *months* and at 9 *months* only fragments of implant cartilage were seen, all closely invested by fibroblasts and collagen fibres. No implant cartilage was found at 6, 14 or 23 months after operation.

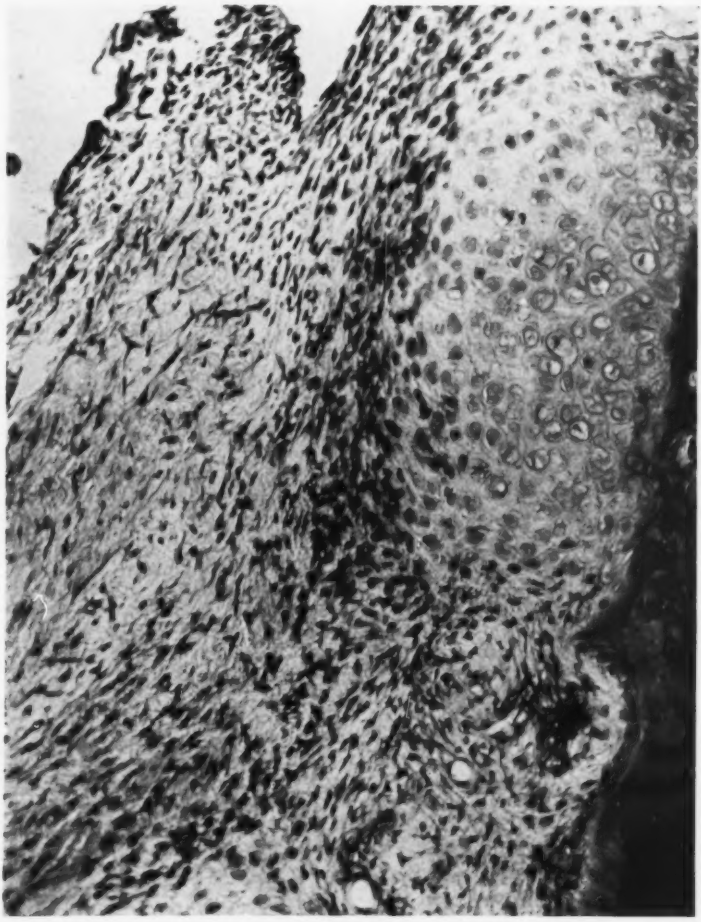

FIG. 7

The proliferating periosteum near the radial tip. This tissue consists of many young fibroblasts, which can be seen transforming into prechondroblasts and chondrocytes. Nearer the radius the calcified cartilage is ossifying. In the lower part of the picture osteoblasts are applied to the newly formed bone without cartilage being present. (Enlargement of part of Figure 6, ×60.)

In the specimens studied at 2, 5 and 23 months the implant, or its replacing fibrous tissue, formed an intra-articular meniscus, separating the radio-capitular articulation into two distinct synovial cavities. This tissue was formed of densely crowded fibroblasts with few fibres present in the early cases. In all later cases the picture was that of collagen fibres, lying in a relatively acellular chondroid matrix.

In the specimens obtained at 3, 4, 6 and 9 months the implant, or its replacing tissue, was adherent to the radial bone (Fig. 5). In the 14-month specimen the investing fibrous tissue at the site of the implant showed a large amount of chondroid matrix. Smaller quantities were present in the earlier specimens.

The radial bone—The cut end of the radius underwent extensive remodelling. There was an initial proliferation of the periosteal fibroblasts. These cells spread in a centripetal direction over the end of the radius (Fig. 6). Other fibroblasts grew from the exposed end of the medullary canal to meet those derived from periosteum forming a fibroblastic cover to the radial tip.

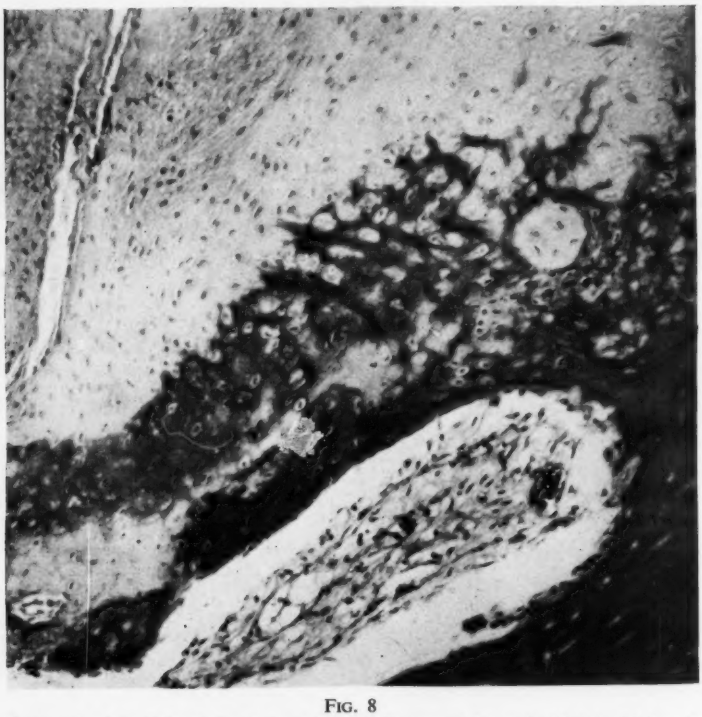

FIG. 8

Fragment of acellular bone from radial tip (*bottom right*) embedded in thickened fibrous capsule (*top left*). The surrounding fibroblasts have become chondrocytes and the calcified cartilage matrix is undergoing endochondral ossification, the new bone being layered on to the old. (×60.) (Whale cartilage implant 6 months.)

Fibroblasts capping the cut bone spicules underwent profound morphological and staining changes. Cells identical with the prechondroblasts of Pritchard (1952), chondroblasts and chondrocytes appeared in that order. The latter lay down clear hyaline cartilage matrix. Nearer to the tips of the bone spicules, these cells became the typical hypertrophic chondrocytes of calcifying cartilage, in which matrix they finally underwent cell death (Fig. 7). This matrix was invaded by dilated capillaries apparently bearing mural osteoblasts. The latter were globose basophilic cells with fine processes giving them a stellate appearance. The osteoblasts laid down bone around the invading blood vessels (Fig. 8).

In the specimens examined at 1 and 6 months this process was seen very clearly, for at the radial periphery the cells of the deep part of the periosteum had proliferated and changed in character to become chondroblasts, which had laid down a substantial thickness of hyaline

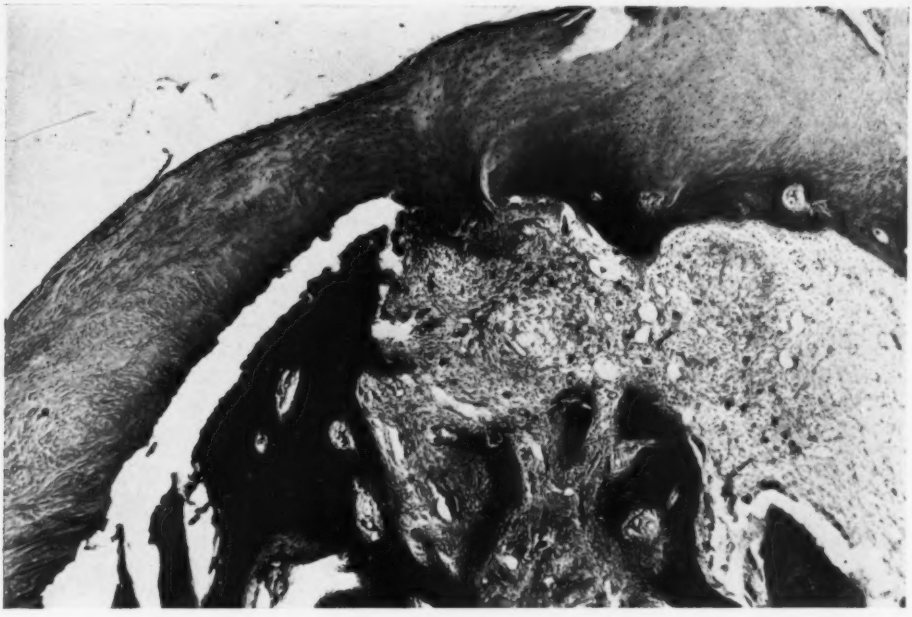

FIG. 9
Part of the new radial articular surface showing the smooth fibrocartilage cover. The separation on the left is an artefact. (×14.) (Whale cartilage implant 23 months.)

cartilage, appearing like a collar round the severed radial neck. The deepest chondrocytes were hypertrophied and the calcified rim of their matrix was invaded by osteoblasts which were laying down new bone matrix (Figs. 6 and 7). Other periosteal fibroblasts near the bone appeared to undergo direct transformation into osteoblasts and to lay down osseous matrix at once (Fig. 7) (Weidenreich 1930).

These two mechanisms of bone production (the first of which is most commonly seen and is the more important) allow extensive remodelling of the articular surface and even a small amount of actual lengthening of the radius.

The 23-month specimen appeared to be a normal joint apart from a fibrous annulus attached to the capsule. The new radial articular surface was smooth and was congruent with the opposite capitular surface. It was composed of hyaline cartilage interlaced with collagen fibres (Fig. 9).

Fixed cartilage homotransplants (biopsy performed after 1, 2, 3, 4 and 23 months). *The implant*—The implant consisted of an excised radial articular cartilage with all but a little of the underlying cortical bone removed with a gouge after decalcification. The cartilage was thickest at the periphery and thin at its centre. Both cartilage and bone were acellular (Fig. 1, *middle*).

At 1 *month* the implant was encapsulated by a layer of fibroblasts, those in the van of the cell invasion laying down reticular (precollagen) fibres in the dead cartilage matrix. The thin centre of the cartilage was ruptured. The dead bony interstices were occupied by fibroblasts and an open network of precollagen fibres.

At 2 *months* the cartilage of the implant was unchanged. The bone interstices were filled with fibroblasts lying in a faintly basophilic matrix, together with precollagen fibres. Some areas were typical of hyaline cartilage matrix.

FIG. 10

FIG. 11

Figure 10—Low-power photomicrograph of site of operation. The implant is acting as an intra-articular meniscus. The radial tip is rounded and covered by periosteogenic fibroblasts and fibrocartilage. The articular surface is smooth and functionally efficient. (×2·2.) (Homotransplant 3 months.) Figure 11—High power from another region of the same experiment. The implanted cartilage shows fracture lines along which invading fibroblasts grow. (×190.)

At 3 *months* the specimen showed fragmentation and invasion of the implant cartilage by capillaries, fibroblasts and fibres. The implant had fine multiple fracture lines at various points in its periphery. The bone interstices were filled with fibroblasts and precollagen fibres, with little suggestion of chondroid matrix (Figs. 10 and 11).

At 4 *months* the specimen showed break-up of the implant, the fragments being separated by crowded fibroblasts, which were invading the newly formed interfaces. The bone interstices were filled in one zone with fibroblastic tissue like that seen in the 2-month specimen, but for the most part the spaces were full of basophilic hyaline cartilage (Fig. 12). Many of the chondrocytes were hypertrophied, and the surrounding matrix was calcified. In one part of the implant capillary invasion had occurred, resulting in the formation of new living perivascular bone (Fig. 13).

At 23 *months* no trace of implant was found. The investing layer of fibrous tissue was covered by synovial membrane. There was a clear joint space lying between it and the capitulum proximally and the remodelled radial tip distally (Fig. 14).

The radial bone—The specimens obtained at 1, 3 *and* 4 *months* showed a histological process like that of the heterotransplants. Growth of fibroblasts from the periosteum formed a cap of tissue over the end of the radius. Fibroblast metaplasia formed chondrocytes. The calcified matrix produced by the latter was transformed into bone matrix by endochondral ossification. Nearer the joint surface fibroblasts were present in large numbers, and were associated with transversely orientated collagen fibres. Clear chondroid matrix was seen between groups of fibres (Fig. 15). In the 2-*month* specimen several zones of pure cellular hyaline cartilage occurred enshrouded by fibroblasts, both at the periphery under the periosteum, and also

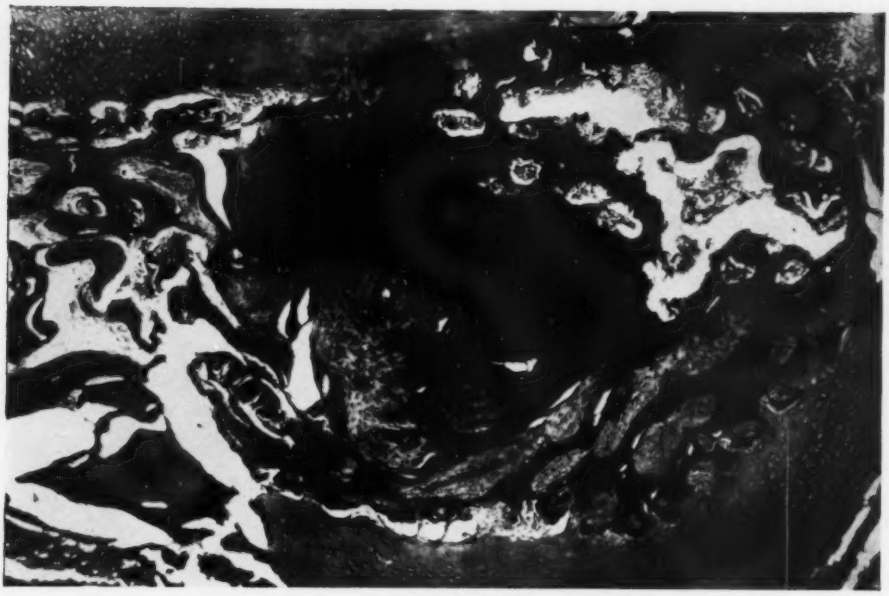

FIG. 12

The implant, showing at the periphery of the picture the acellular cartilage and in the centre new cellular hyaline cartilage (some of it deeply basophilic) lying between the dead bone trabeculae of the implant. (×12.) (Homotransplant 4 months.)

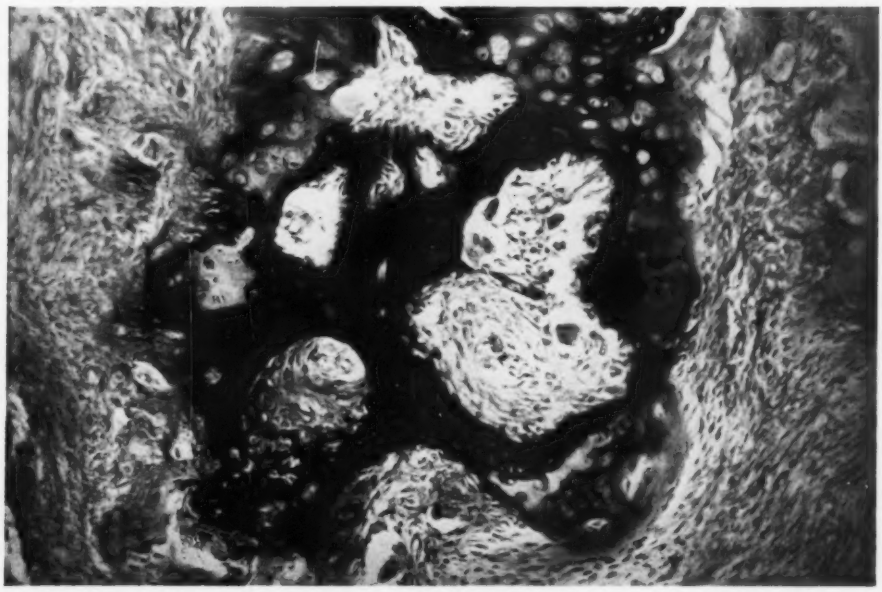

FIG. 13

Another site from the implant of the same experiment showing new calcified cartilage and active endochondral ossification occurring in the middle of the bone interstices of the implant (not shown). (×52.)

in the fibrocartilage cap. This appearance is so anomalous, when compared with the other specimens, that it must be assumed that the hyaline cartilage had grown from cell remnants of the epiphysial plate of the radius which had not been completely removed at operation.

At 23 *months* the specimen appeared as a relatively normal joint, without intra-articular meniscus, or any sign of the implant. The cut end of the radius had been reconstituted of dense cortical bone. The bone was separated from the overlying fibrocartilage by a deeply stained basophilic line. Smooth articular fibrocartilage covered the whole of the peripheral

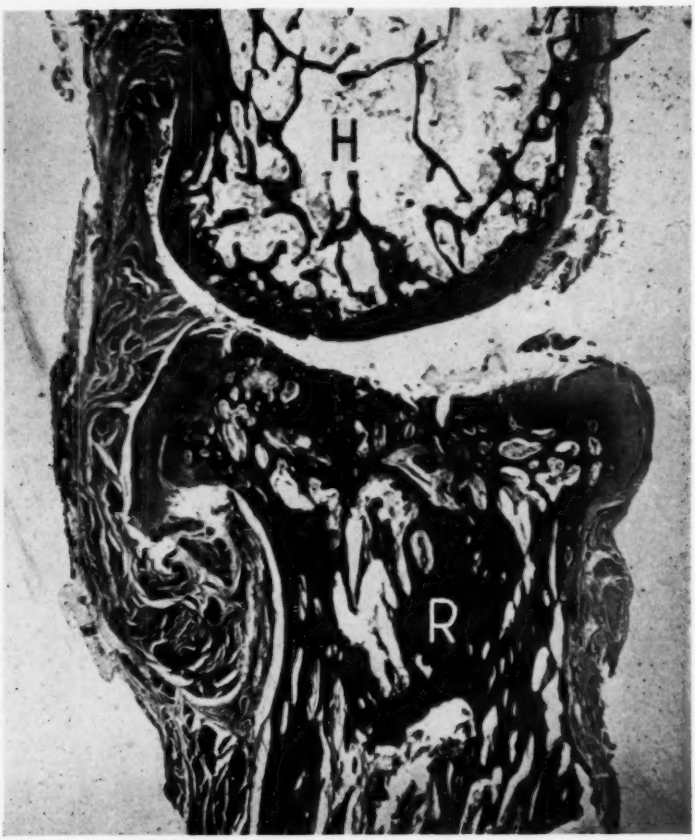

FIG. 14

Low-power photomicrograph showing the joint surfaces twenty-three months after homotransplantation. No trace of the implant was found; the radial articular surface was composed of hyaline and fibrocartilage which covered all except a small part of the new radial cortical bone. (×3·5.)

two-thirds of the end of the radius (Fig. 16). In places its surface was frayed, and frond-like fibres of collagen projected into the joint space. The depressed central third of the articular surface was in places covered by a layer of densely packed fibroblasts, but in other places the osseous matrix was quite bare. As might be expected, the cartilage covering the capitulum was also frayed and abraded (Figs. 17 and 18).

Fixed cartilage autotransplants (biopsy performed after 5, 6, 6, 9, 13 and 14 months). *The implant*—The histology of the freshly implanted tissue was the same as in the homotransplants (dead cartilage with small amounts of attached dead subchondral cortical bone).

At 5 *months* the cartilage of the implant was fragmented, with invasion of the dead cartilage by macrophages, fibroblasts and collagen fibres. In the interstices of the dead bone there was one small area of cartilage and new bone production. A few areas of bone resorption were seen. In most areas the interstices of the dead implant bone were filled with fibroblasts and collagen fibres. The implant was functioning as an intra-articular meniscus.

In one 6-*month* specimen nearly half the implant cartilage had been replaced by infiltrating fibroblasts, collagen fibres and chondroid matrix. At the periphery of the implant the bone

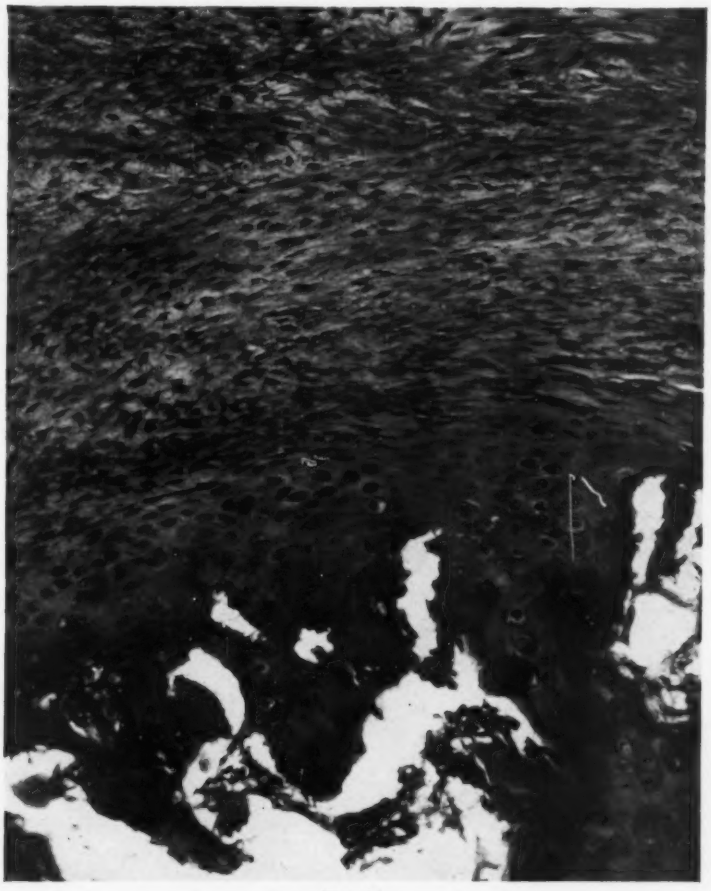

FIG. 15

Spicule of cortical bone from the radial tip showing transformation of fibroblasts into prechondroblasts, chondroblasts, mature, hypertrophic and degenerating chondrocytes in a calcified matrix, and invasion of the latter by osteoblast-bearing capillaries to form new perivascular bone. (×60.) (Homotransplant 3 months.)

interstices were full of basophilic, calcified hyaline cartilage, which was the site for the production of considerable quantities of new perivascular bone (Fig. 19). Centrally the interstices were full of fibroblasts and collagen fibres. The implant was functioning as a meniscus.

In the other 6-*month* specimen the implant was firmly attached to the radial head without any intervening synovial space. The implant cartilage was broken up and the fragments

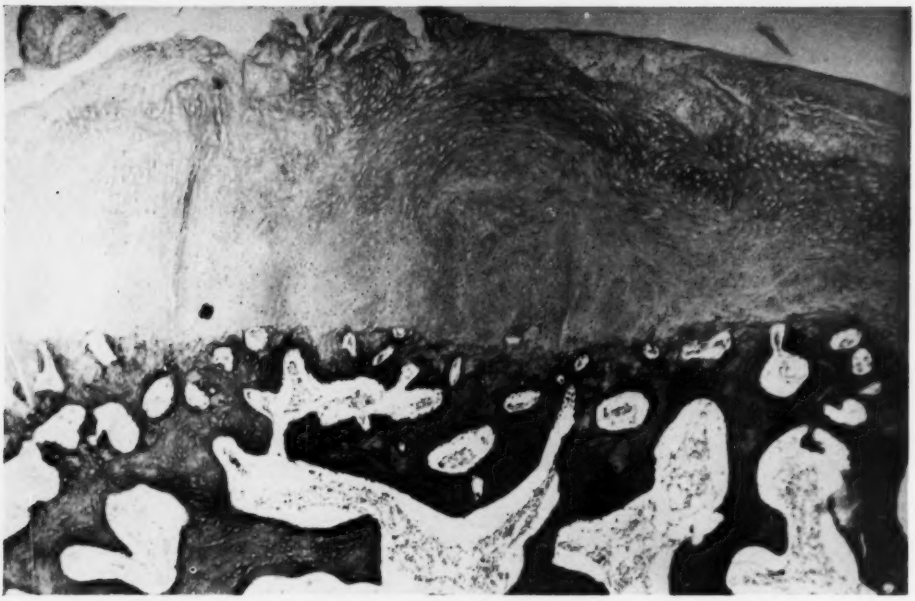

FIG. 16

Low-power photomicrograph showing smooth fibrocartilage forming the radial articular surface, from the peripheral two-thirds. Note the well formed barrier of cortical bone. (×14.) (Homotransplant 23 months.)

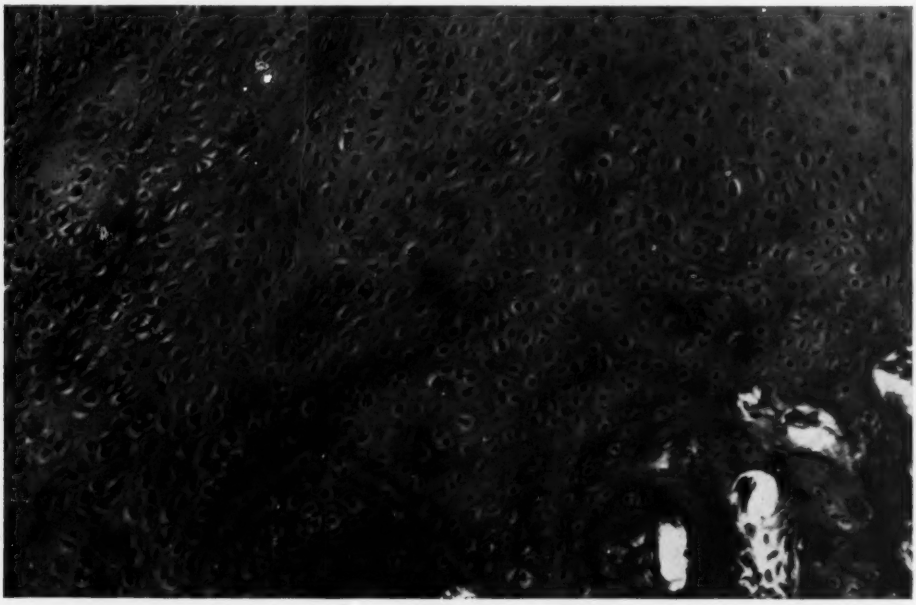

FIG. 17

High-power view showing the cellular structure of the articular surface from the same area as Figure 16. (×60.)

were invaded peripherally by fibroblasts and collagen fibres. No dead implant bone was visible. On the deep surface of the implant fibroblasts merged into chondroblasts and chondrocytes, lying in a hyaline cartilage matrix. This was undergoing endochondral ossification adjacent to the existing radial bone spicules. The implant was therefore itself the actual radial articular surface undergoing active replacement by host tissue (Figs. 20 to 22).

FIG. 18
Another area showing fibrocartilage from the central part of the articular surface. (×60.) (Homotransplant 23 months.)

In the 9-*month* specimen the remaining two fragments of implant cartilage were infiltrated by fibroblasts and collagen fibres. The interstices of the implanted bone were filled with hyaline cartilage, some of it calcified. There was a considerable amount of perivascular new bone. In other parts the interstices contained fibroblasts and collagen fibres.

No implant tissue was found in either the 13-month or 14-month specimen.

The radial bone—In the 5-*month* specimen the fundamental processes observed in the 1-, 2-, 3- and 4-month homotransplant experiments were continued. The fibroblast tissue arising from the periosteum had grown over nearly the whole radial end and formed the bearing surface

between radius and implant meniscus. Progressive ossification of calcified cartilage covering bone spicules was still in progress. These chondrocytes were similarly derived from the fibroblasts covering the radial bone. The few places where bone spicules were not covered by the pad of fibroblasts showed no growth of bone and were in direct articular relationship with the implant, which was functioning as a meniscus.

Much of one 6-month specimen of radial bone was lost (through a technical fault) although the implant was described above.

The histological picture in the other 6-*month* specimen was of special importance. The implant was the articulating surface and was attached to the radial bone by encapsulating

FIG. 19

Low-power photomicrograph of the implant showing the implant cartilage (*top left*), the acellular bone trabeculae, the hyaline cartilage in the interstices, and the endochondral ossification in the latter. (×14.) (Autotransplant 6 months.)

and invading fibroblasts. These were continuous with those becoming chondrocytes which produced the cartilage to form the matrix for the ingrowing capillaries and their perivascular bone of the new cortex (Figs. 20 to 22).

The 9-*month* specimen showed much new cortical bone at the radial tip. This was covered by fibrocartilage derived from the periosteum which had encapsulated the two small remaining fragments of the original implant. Actual bone formation in the radial tip was confined to a few limited areas.

The 13-*month* specimen showed ossification of the radial tip at the central point of the bone end, evidently brought about without endochondral ossification. In other places, endochondral ossification had occurred while a few bone spicules were full of erosion cavities, occupied by osteoclasts. The radial bone tip was separated from the synovial membrane lining the radiocapitular joint by a pad of transversely orientated fibrocartilage (occupying the site of the implant) some 0·25 centimetre thick. This was split transversely by numerous bursa-like spaces (Fig. 23).

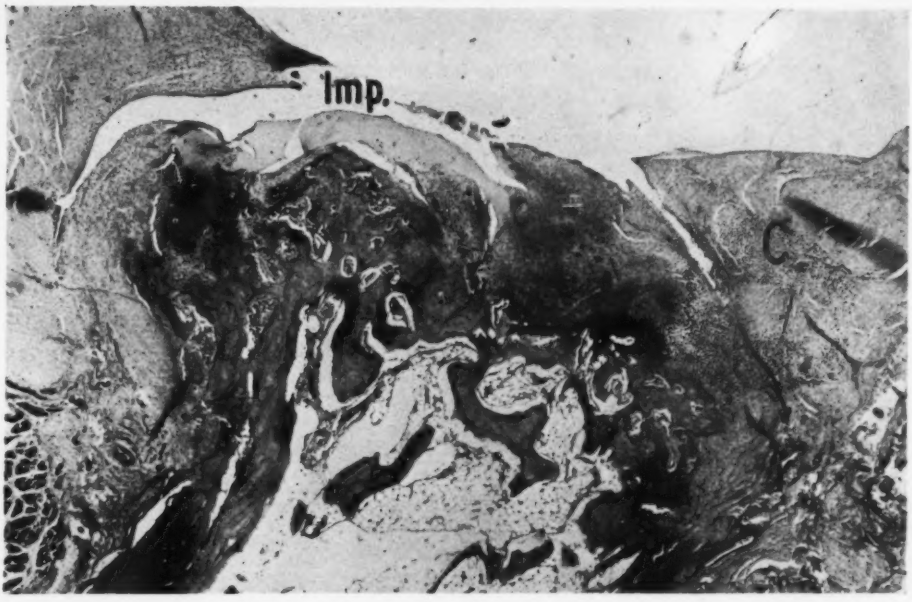

FIG. 20

Radial tip showing the remnant of the implant (Imp.) invaded from the periphery and deep surface by fibroblasts. From the deeper zones chondroblasts are laying down cartilage. This is being transformed by endochondral ossification into cortical bone. There is some capsular thickening (C) and this projects into the joint cavity as a synovial pad. (×10.) (Autotransplant 6 months.)

FIG. 21

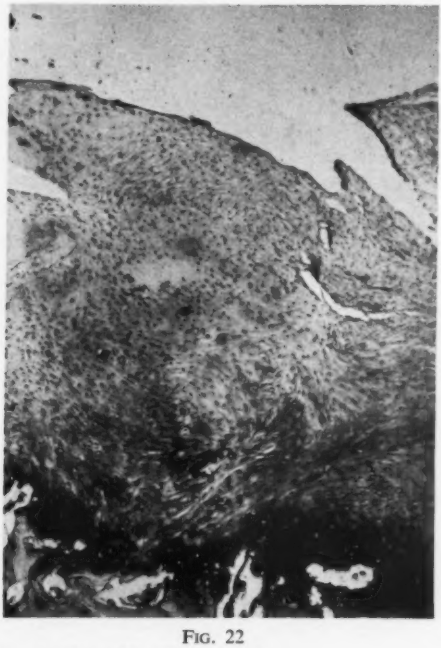

FIG. 22

Adjacent zones from the radial tip shown in Figure 20. (Both, ×41.)

FIG. 23

Radial end showing endochondral ossification producing new cortical bone. The radius was capped by a mass of fibrocartilage split by bursa-like spaces. (×9·5.) (Autotransplant 13 months.)

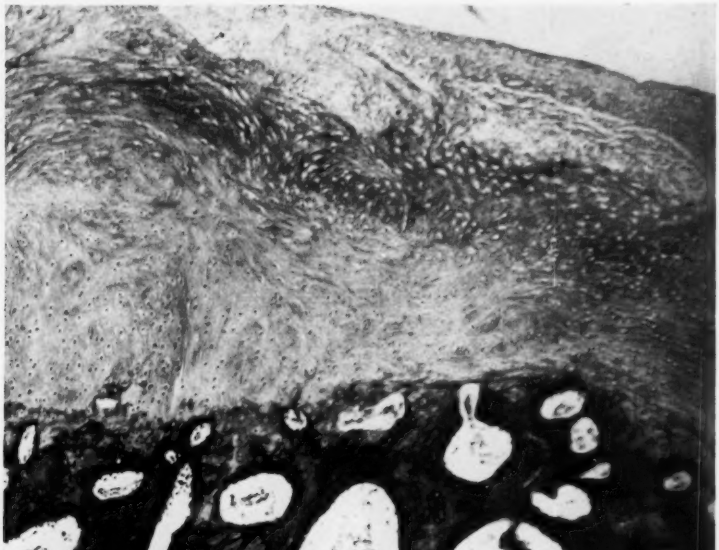

FIG. 24

New articular surface of radius in a macroscopically normal joint (×60.) (Autotransplant 14 months.)

The 14-*month* specimen showed an almost normal radiocapitular joint. The radial end was reconstituted by cortical bone which sealed the medullary canal except for one small central area. There was a distinct basophilic line at the osteochondral junction. The cartilage had a hyaline matrix and only differed from the humeral articular cartilage by virtue of its content of collagen fibres (Fig. 24).

Simple excision of radial head (biopsy performed at 1, 4, 6, 7, 13, 13 and 14 months). At 1 *month* the radial tip was covered with fibroblasts. In the deeper part near the bone these showed transformation to chondroblasts and chondrocytes. Their cartilage matrix covered some of the bone spicules, and was undergoing progressive endochondral ossification. A considerable amount of new bone had thus been formed. At the same time spicules of the original bone were undergoing active destruction in the presence of osteoclasts.

FIG. 25

The central part of the articular surface of the radius, showing peripheral cartilage and central bare cortical bone. (×12.) (Excision of radial head 6 months.)

At 4 *months* the radial tip showed a similar picture of ossification. There was a thick pad of fibroblast and collagen tissue overlying the radial bone and forming the actual articulating surface. Isolated in this pad there was a focus of hyaline cartilage and endochondral ossification, complete with its own blood vessels. The chondroblasts at the periphery merged gradually with the surrounding fibroblasts.

At 6 *months* the outer third of the radial bone end was covered by a layer of fibroblasts, capillaries and collagen fibres with a minimal amount of endochondral new bone in the cartilage. Over the central two-thirds of the end of the radius the bone was covered irregularly by a loose tissue of fibroblasts, irregularly arranged fibres and many capillaries (Fig. 25).

Similarly in the 13-*month* specimens only the periphery of the radial tip showed cortical bone. This had been formed by endochondral ossification as a plate partly closing the end of the radius. It was covered by a thick layer of well organised articular fibrocartilage. The rest of the radial end was a bare bony surface. Some of the spicules showed osteoclastic

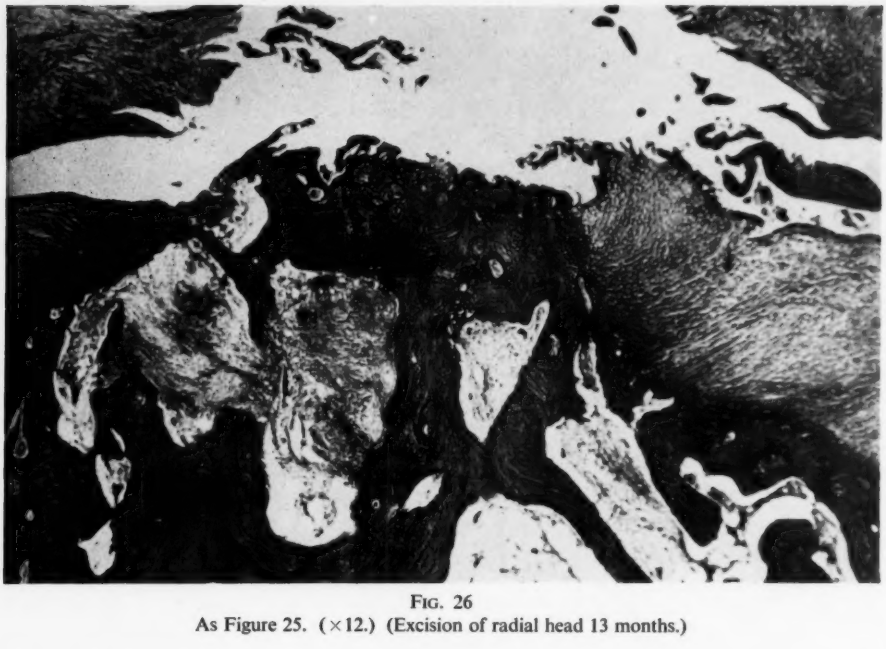

FIG. 26
As Figure 25. (×12.) (Excision of radial head 13 months.)

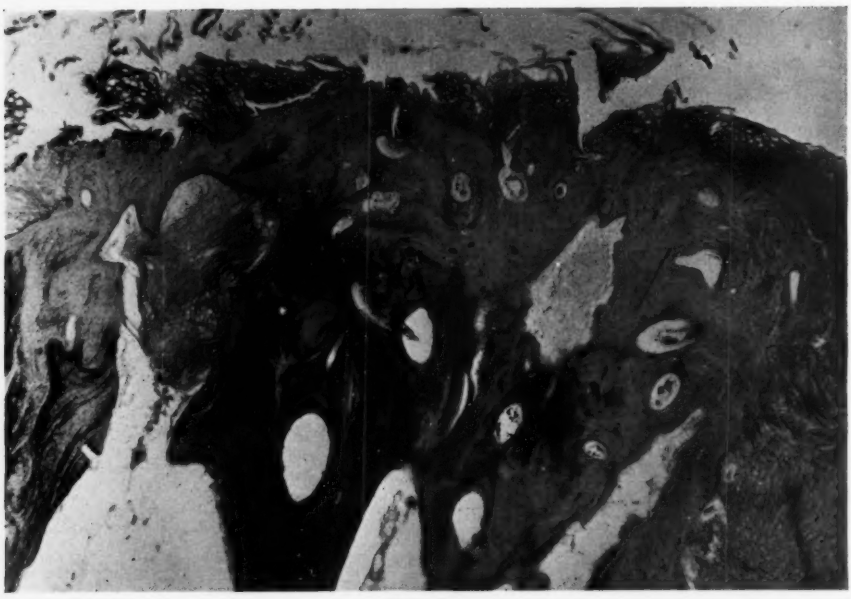

FIG. 27
As Figure 25. (×52.) (Excision of radial head 14 months.)

activity. The opposite humeral articular surface was abraded and torn. It appeared that direct frictional contact had prevented the initial overgrowth of fibroblasts and thus prevented the organisation of a new radial articular surface (Fig. 26).

The 14-*month* specimen presented a similar picture. Peripherally the radial end was of normal cortical bone covered by fibrocartilage. Centrally, the bone spicules were either bare, or covered by hypertrophied masses of hyaline cartilage irregularly arranged and interspersed with groups of frond-like projecting collagen fibres. This irregular joint surface had evidently caused considerable damage to the humeral articular cartilage, the surface of which was irregular and torn (Fig. 27).

DISCUSSION

The method of healing of the cut radial bone—The tissue reactions resemble those initiated during repair of a simple bone fracture. We believe that the proliferation of cells from the cut periosteum and joint capsule is of fundamental importance. This has been emphasised by Pritchard and Ruzicka (1950) as one of the key processes in fracture repair. This study bears witness yet again to the astonishing way in which fibroblasts can assume different functions. This poses a difficult problem in terminology. Throughout this paper we have used the term " fibroblast " because it is in general use. Though strictly speaking the fibroblast might be regarded as a cell concerned in the production of collagen fibres, our observations suggest that this cell, derived from the periosteum, is a pluripotential cell with the inherent ability to form collagen, cartilage or bone under different conditions. The most striking feature seen in every experiment was the conversion of fibroblasts into cartilage-producing cells. There is direct experimental evidence for this in the appearance of cartilage (and bone) in cultured periosteal explants (Fell 1932, 1933), but it has also been emphasised by most authors describing the histology of fracture repair (Bast *et al.* 1925, Blaisdell and Cowan 1926, Enneking 1948).

Ollier (1867) was interested in somewhat similar problems to our own, namely the restoration of an articular surface after joint resection. His brilliant experimental operations on rabbits, using many different types of periosteal transplants, showed convincingly that a new articular surface was possible only if the periosteum was intact. Our histological results bear out his deductions, and moreover show precisely why he was right.

The role of the cartilage implant—The histological evidence from our experiments supports the view that cartilage implanted to act as a temporary joint surface does in fact do so. Because of imperfections in our experimental technique, results did not always follow precisely the same pattern.

The main difficulty encountered was a post-operative loosening of the implant capping the cut radial end (caused by fracture of the stem in the whale cartilage implants, and by too loose a fit in the monkey cartilage implants). In these cases the implant became ensheathed in fibroblast tissue derived from periosteum and was finally converted into collagen. Concurrently it functioned as an intra-articular meniscus, transversely separating the radio-capitular joint into two parts. The importance of the implant was that it allowed the subjacent development of a smooth joint surface capping the radius.

When the implant remained permanently adherent to the radius it formed a perfect joint surface. It was slowly invaded from its deep and peripheral aspects by fibroblast tissue arising from the periosteum, capsule and, to a minimal extent, medullary canal. This same tissue was first converted into cartilage and later, by endochondral ossification, into a plate of cortical bone.

The fundamental mechanism of healing was the same whether or not cartilage was implanted as a temporary surface. But the end result, as judged by the smoothness of the radial articular surface, was better when a cartilage implant was used than when the radial head was simply excised. It seems probable that this was due to the protection afforded by

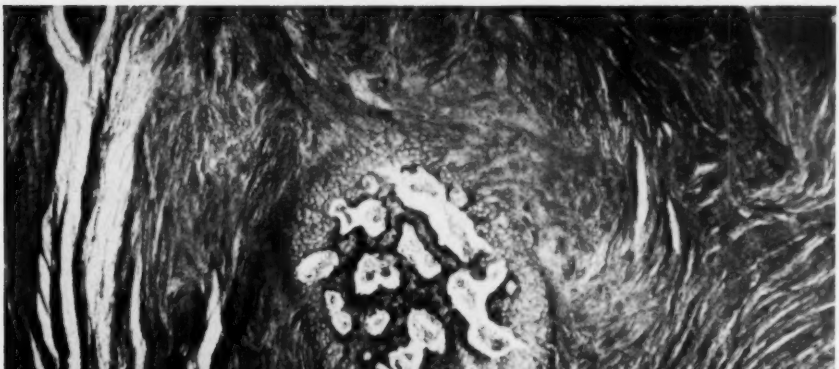

FIG. 28

A small centre of endochondral ossification occurring in a nodule of hyaline cartilage embedded in the thickened joint capsule. (×14.) (Excision of radial head 6 months.)

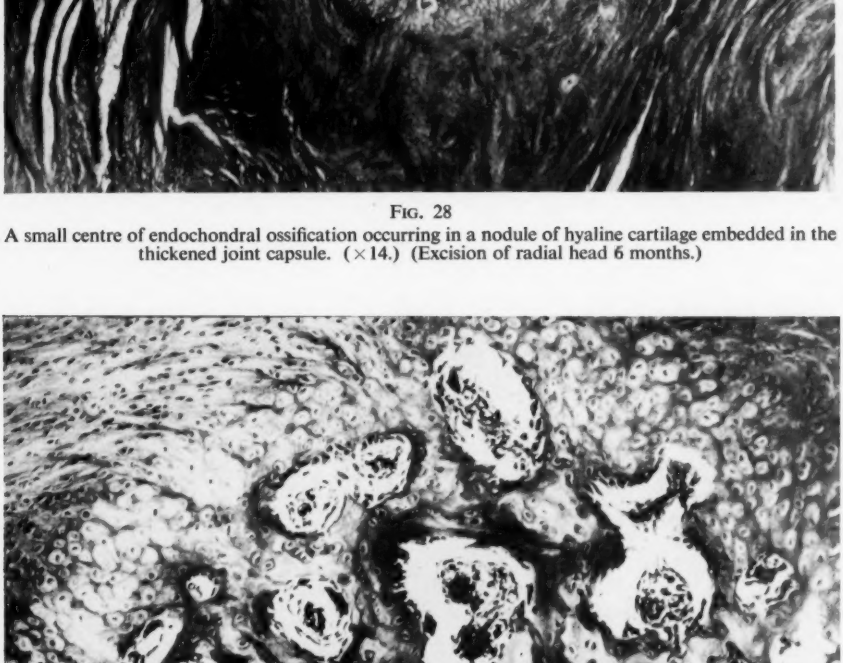

FIG. 29

Detail of the ossification centre showing capillary invasion of calcified cartilage and pericapillary ossification. (×60.)

the implant, which allowed the initial growth of the fibroblastic cap to cover the cut end of the bone. As Ollier's (1867) experiments suggested, without this fibroblastic cap there can be no new joint surface.

Possible factors inducing the transformation of fibroblasts to chondroblasts—Three observations are of direct relevance to the solution of this problem: 1) It is well known, and has been shown again in these studies, that fibroblast transformation always occurs at the ends of bone spicules, giving rise to the appearance of a hyaline cap (Figs. 15 and 22). 2) In two specimens, months after simple excision of the radial head, a fragment of dead bone was found embedded in the thickened fibrous periosteum. The fibroblasts were undergoing transformation to chondroblasts and this new cartilage was undergoing endochondral ossification in association with the fragment of dead bone (Figs. 8, 28 and 29). 3) In both dead autogenous and dead homogenous implants, fibroblast transformation to hyaline cartilage occurred in the interstices of the dead bone. In places this was also undergoing endochondral ossification (Figs. 12 and 19).

These three observations indicate that bone—even dead, acellular bone from another individual—is capable of inducing hyaline cartilage formation which in its turn can become ossified.

Here then is a significant piece of evidence indicating another factor that may control chondrification and subsequent endochondral ossification. Pritchard and Ruzicka (1950) discussed fully the evidence for and against another two important factors, namely the vascularity of fibroblast tissue, and the function of mechanical stress and strain acting on such tissue. There is strong experimental evidence that both factors are important. Pritchard (1952) and others have proceeded further and studied the histochemical aspects of this fibroblast transformation. It is clear that the essential change is an alteration in the enzymatic structure of the cell. This fits in well with the hypothesis suggested by these observations, that chondrification and ossification are initiated through chemical induction by the proximity of non-cellular osseous intercellular substance.

CONCLUSIONS

The experiments were performed to answer three main questions. These and our answers may be summarised as follows.

What is the precise mechanism of healing of a raw bony surface in a joint? What cells are involved? Where do they originate?—In all the implant experiments and in the control series the fundamental mechanism of healing was similar.

1. A massive proliferation of fibroblasts occurred from the cut periosteum, from the cut joint capsule, and to a lesser extent from the medullary canal.

2. Fibroblasts grew centripetally in the first few weeks after operation, attempting to form a " fibroblast cap " to the cut bone end.

3. Fibroblasts of this cap near the cut bone spicules metamorphosed to become prechondroblasts, chondroblasts laying down cartilage matrix, and hypertrophied (alkaline phosphatase-secreting) chondrocytes lying in a calcified matrix.

4. This calcified cartilage matrix was invaded by dilated capillaries probably bearing osteoblasts which laid down perivascular (endochondral) bone.

5. Some of the cells of projecting bone spicules died and their matrix was eroded in the presence of many osteoclasts.

6. In the control experiments of simple excision of the radial head new bone was produced at the periphery only by processes (3) and (4). This sealed off the underlying peripheral cortical bone from the superficially placed peripheral articular surface of fibrocartilage. At about a year from operation the central portion of the articular surface was still formed of bare bone, or of bone spicules covered by a thin layer of irregularly arranged collagen fibres. The opposite capitular articular cartilage was badly eroded.

Does the introduction of a dead cartilage implant over the raw bone end affect in any way the final constitution of the new articular surface?—In the implant experiments the new bone produced by processes (3) and (4) formed, after about a year, a complete cortical plate which entirely sealed off the cut end of the radius and left a superficially placed articular covering of smooth fibrocartilage, closely resembling a normal joint surface. The opposite capitular articular surface was normal.

What is the final fate of such an implant?—Whale cartilage implants underwent replacement by fibroblasts and collagen fibres, and took about nine months to disappear.

The cartilage of fixed autotransplants and homotransplants underwent similar gradual replacement, and took about the same time in each case. The dead bone, implanted in association with the cartilage in both cases, acted as a nidus for hyaline cartilage production by chondrocytes derived from fibroblasts. This cartilage underwent endochondral ossification. This observation suggests that induction by non-cellular osseous material is a factor in chondrification and ossification.

All the implants functioned as temporary articular menisci or in some cases as temporary radial articular surfaces. They were always replaced by a permanent fibrocartilaginous meniscus, or a fibrocartilaginous articular surface. An implant did, in fact, always act as a temporary protecting cap and mould for the subjacent growth of fibroblasts which was necessary for the production of a satisfactory new joint surface.

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THE OSSIFICATION AND VASCULARISATION OF THE TARSAL NAVICULAR AND THEIR RELATION TO KÖHLER'S DISEASE

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Study of the nature of the abnormal radiographic appearances in the tarsal navicular bone first described by Köhler (1908) presents difficulties which arise in any mild and self-limiting condition. Pathological specimens are seldom available and can demonstrate only a static phase in a continually changing process occurring in a growing bone. Köhler's (1928) final writing on the subject represents a careful assessment of the situation, particularly so far

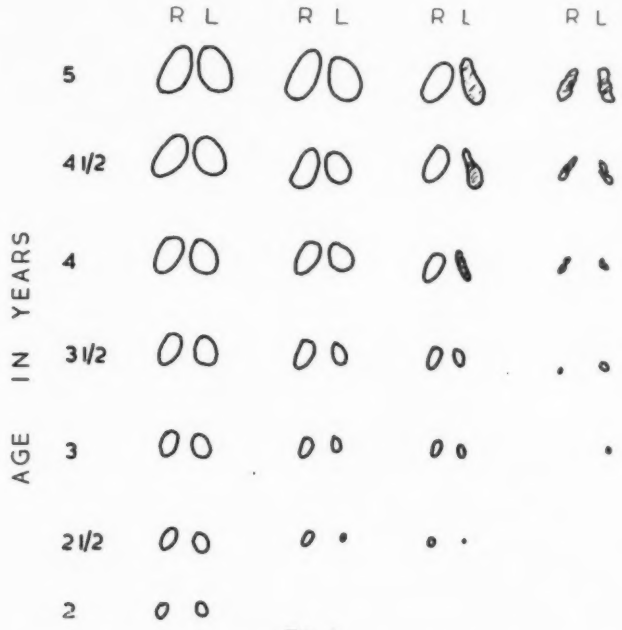

FIG. 1

Tracings of the outlines of the navicular from lateral radiographs of both feet in four children. Radiographs were taken every six months between two and five years. These examples demonstrate normal and abnormal ossification.

as etiology is concerned, and very little knowledge has been added since. The problem has to be approached indirectly, and the object of this paper is to report an investigation into normal and abnormal patterns of ossification and vascularisation of the growing tarsal navicular and their relation to Köhler's disease. Three groups of material have been collected and analysed: first, serial radiographs of fifty-two normal children's feet; second, post-mortem injection studies using the technique developed at the Nuffield Orthopaedic Centre (Trueta and Harrison 1953); and third, the records of sixty-two children with Köhler's disease.

NORMAL AND ABNORMAL OSSIFICATION OF THE NAVICULAR

Karp (1937) studied radiographs of the feet of fifty children (twenty-five girls and twenty-five boys) taken every six months between the ages of nine months and four and a half years, and concluded that the average age of appearance of the ossific nucleus was between eighteen months and two years in girls and between two and a half and three years in boys. He also pointed out that not infrequently there were irregularities in ossification, the nucleus being sometimes flattened and occasionally fragmented or dense.

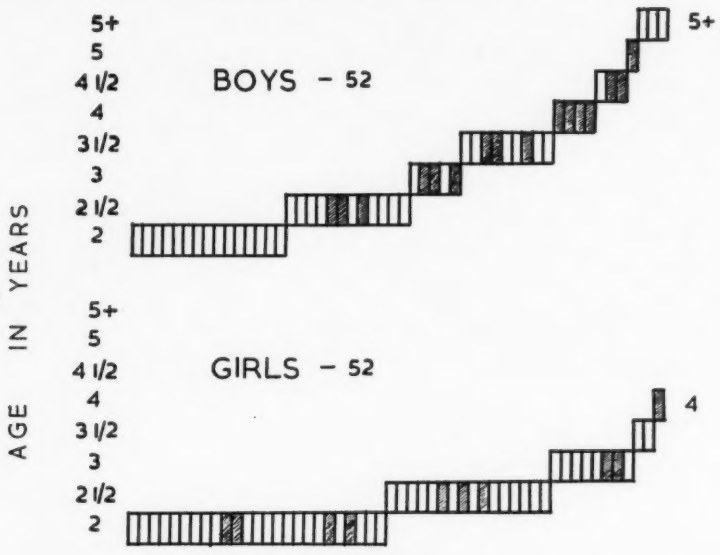

FIG. 2

Charts showing the differences in development of the navicular in twenty-six boys and twenty-six girls (fifty-two feet in each group). Each rectangle represents a single navicular and is shown at the age at which the nucleus first appears. Cross-hatching indicates a navicular whose ossification is abnormal. The three rectangles marked 5+ in the boys' group indicate naviculars in which the nuclei had not appeared in the last films available at five years old.

In the present investigation serial radiographs of the feet of fifty-two normal children (twenty-six girls and twenty-six boys) were available, lateral films of both feet being taken at six-monthly intervals between the ages of two and five years inclusive. The height and weight of the child were also recorded. The sequence of ossification was observed by tracing the outline of both naviculars at 2, 2½, 3, 3½, 4, 4½ and 5 years in each of the fifty-two children. Figure 1 shows four examples. In the first, a girl, the nucleus on both sides is well formed at two years and continues to develop normally. The second shows no abnormality of ossification but there is a definite difference in size between the two sides. In the third, the nucleus on the left side, which has lagged behind the right in development, becomes flattened and shows increased density about a year after its appearance. By five years the navicular, although still somewhat flattened, is regaining its normal structure. In the fourth example, both naviculars are delayed in appearance till three years on the left and three and a half years on the right, and they both show considerable irregularity in shape and odd patches of increased density. From a study of the full series it becomes clear that the pattern of development of the navicular is very variable. Abnormalities of ossification are common: they may consist of only minor irregularities in shape and size; or there may be gross changes that are apparently indistinguishable from those seen in Köhler's disease.

Figure 2 is a diagram made to illustrate differences of development in boys and girls. Each rectangle represents a single navicular and is shown at the age at which its bony nucleus is first seen. Cross-hatching indicates a nucleus that shows abnormal ossification at the time of its first appearance or later. The series starts at an older age than Karp's, and in the feet that show a well formed nucleus in the first film at two years, it is not possible to say exactly at what age that particular nucleus appeared. Similarly, it is not possible to say how many of the retarded naviculars might develop changes between five and six years, the age at which Köhler's disease is common in boys. The three empty rectangles at the top of the boys' group indicate three feet in which the navicular had not appeared by five years, so that these might well show structural abnormalities at the time of their first appearance or later. Three conclusions, which are similar to Karp's, may be drawn from this survey: first, ossification occurs later in boys than girls; second, abnormalities are commoner in boys than in girls; and third, they are more frequent in naviculars that appear late.

THE VASCULARISATION OF THE GROWING NAVICULAR

It is often said that the navicular has a poor blood supply, but it is difficult to find precisely how and when this impression arose. Köhler (1928) wrote that " one roentgenologist determined on the grounds of anatomical research that the region of the scaphoid was poorly vascularised " but he omitted the name of the roentgenologist. It seems likely from other references that he was quoting the Italian Balli; unfortunately this author's papers are published in journals which are not available in any library in England. After a careful search, only two contributions have been found in which an attempt has been made to study the vascularisation of the bone (Velluda 1928, Zchakaja 1932); neither paper is adequately illustrated, but both

FIG. 3
Spalteholz photograph of an injected navicular from a boy aged eight weeks. (×3.)

authors claimed that the bone was well supplied by radially penetrating vessels. In order to clarify this point, post-mortem injection studies were carried out on twenty-one naviculars at varying ages between birth and nineteen years.

It has not been possible to determine the source of the vessels entering the navicular bone by the method used in this investigation, but the following description was given by Velluda (1928). A branch from the dorsalis pedis artery crosses the dorsal surface of the navicular bone and gives off three to five branches. In most cases this vessel anastomoses with the medial plantar artery, forming an arcade around the tuberosity. Occasionally, the bone may

receive small branches direct from the dorsalis pedis itself. The plantar surface is supplied by branches from the medial plantar artery.

After injection of Micropaque* by way of the external iliac artery (this is perfectly satisfactory in children) or the lower end of the femoral artery, the navicular is removed. It is decalcified, then cleared by the Spalteholz technique and studied under a dissecting microscope. All the illustrations in this paper are either fine-grain radiographs or Spalteholz photographs taken through the whole navicular from anterior to posterior. For the sake of clarity, each picture is orientated with the dorsal surface uppermost and the tuberosity on the right hand side (the negative being reversed if necessary).

Specimens at eight weeks (Fig. 3) and eight months (Fig. 4) show that the navicular is surrounded by a dense perichondrial network of vessels on the non-articular surfaces, and

FIG. 4
Spalteholz photograph of an injected navicular from a girl aged eight months. (×3.)

from this numerous arteries penetrate towards the centre of the cartilage. At twenty-one months (Fig. 5) the basic pattern is the same. The earliest appearance of an ossific nucleus is seen in Figure 6: bone has been laid down in relation to a single artery and vein. From this point three courses are theoretically possible. As the nucleus enlarges, it might be supplied by a single artery for a relatively short period, the other radial vessels becoming rapidly incorporated and forming a dense anastomotic network throughout the bone. Alternatively, separate centres of ossification might develop around several penetrating vessels. This probably can occur since clinical radiographs suggest that the bone does sometimes ossify from several centres, but it has not been found in any of the specimens in the present series. Finally, the nucleus might remain nourished by a single vessel until the age of five or six years, the radial vessels only entering the bone at a later date. Six naviculars between the ages of three and five years were available, and these suggest that the first pattern is the most usual. Figure 7 is a fine-grain radiograph of a navicular from a child three and a half years old. By studying the specimen in Spalteholz medium it can be seen that six arteries enter the bone and anastomose together.

* Berlin blue is not recommended for injection in children as it may produce widespread discoloration of the skin, including the face.

Zchakaja (1932) examined four specimens between four and five years and found that on average eight to ten vessels penetrated the bony nucleus. His rather high figure, compared with that found in the present investigation, is probably explained by the fact that he studied only

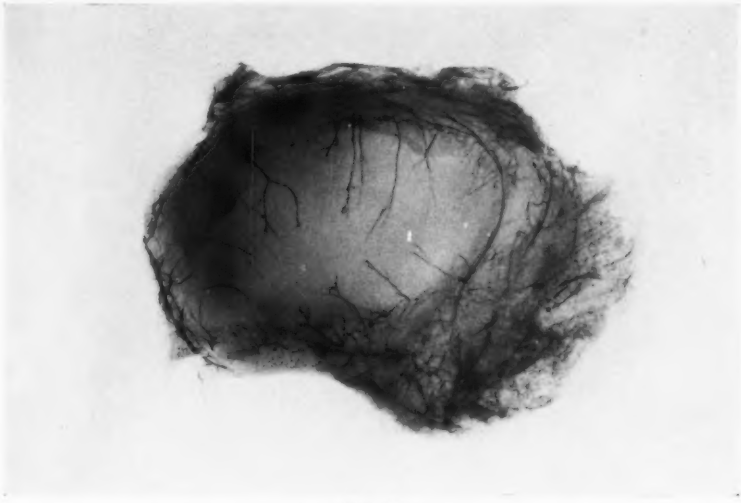

FIG. 5
Fine-grain radiograph of an injected navicular from a girl aged twenty-one months. (×2.)

FIG. 6
Fine-grain radiograph of an injected navicular from a girl aged twenty-one months. (×2.) This is from the same child (opposite foot) as that illustrated in Figure 5. The first sign of ossification is seen: bone being laid down in relation to a single artery and vein. The vessel appearing to enter the nucleus to the right of its centre can be seen to be passing in front of it in the Spalteholz specimen.

radiographs. Vessels that appear to penetrate the bone may in fact be seen to pass in front of or behind it in the Spalteholz specimen. Zchakaja also gave figures for the other tarsal bones at the same age: cuboid, six to eight vessels; medial cuneiform, eight to ten vessels; intermediate

FIG. 7

Fine-grain radiograph of an injected and decalcified navicular from a girl aged three and a half years. (×2.) From a study of the Spalteholz specimen six vessels are seen to enter the central bony nucleus which is outlined by an anastomotic network.

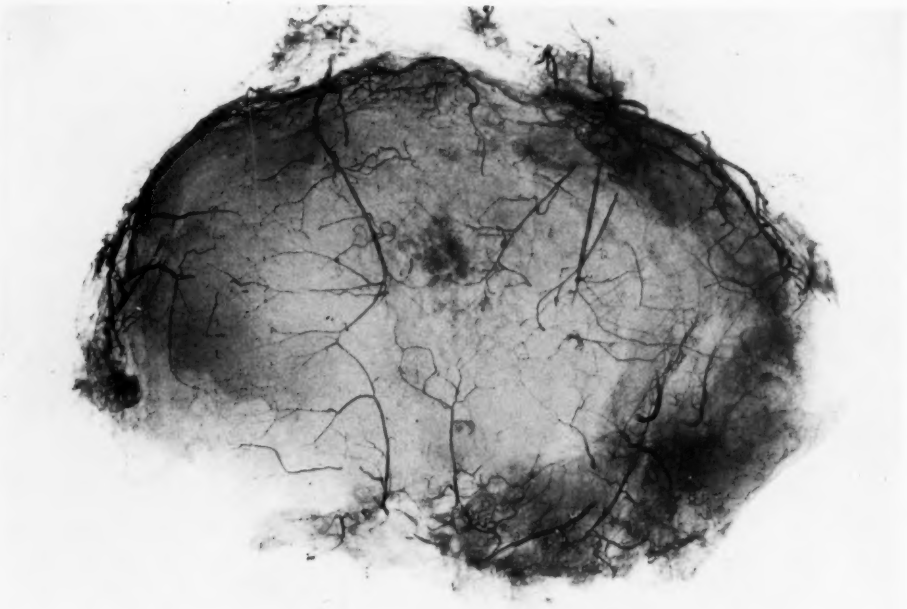

FIG. 8

Fine-grain radiograph of an injected and decalcified navicular from a girl aged seventeen years. (×2.)

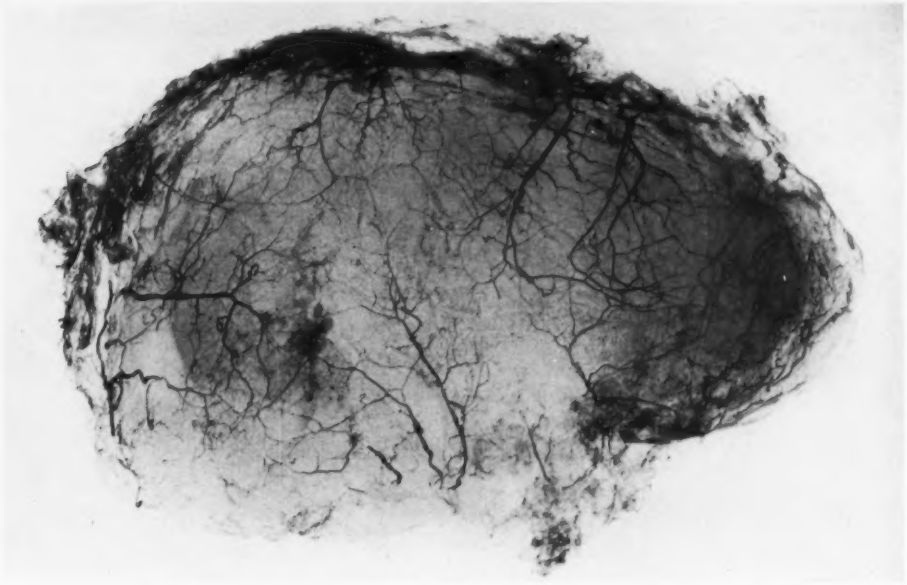

FIG. 9
Fine-grain radiograph of an injected and decalcified navicular from a youth aged nineteen years. (×2.)

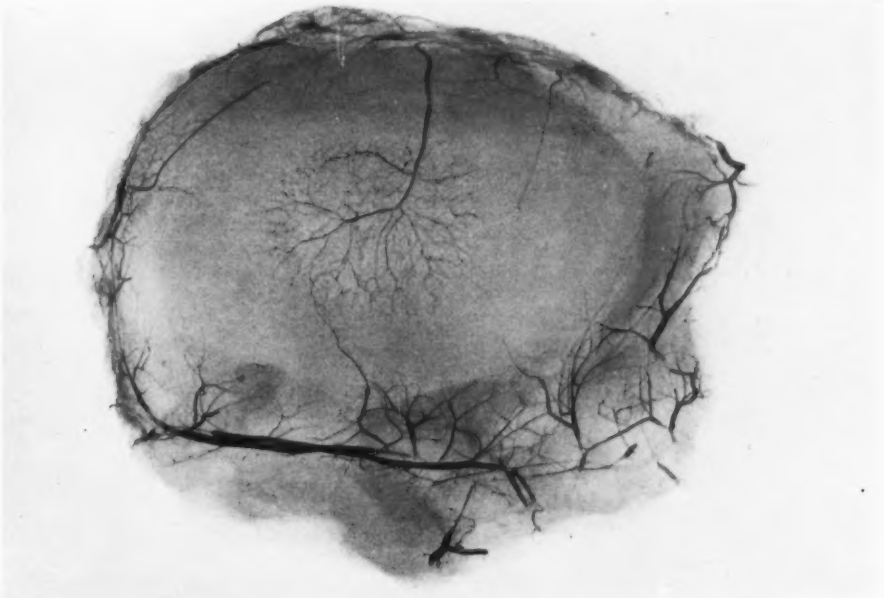

FIG. 10
Fine-grain radiograph of an injected and decalcified navicular from a girl aged four years. (×2.)
A single main artery from the dorsal surface branches and outlines the whole of the central bony nucleus.
A few smaller vessels also penetrate but take little part in the main anastomotic network.

cuneiform, seven to eight vessels; lateral cuneiform, ten to eleven vessels. Although these figures may be high, as with the navicular, they suggest that there is normally little difference between the relative vascularisation of the tarsal bones.

The theory that there is a rapid incorporation of the chondral vessels into the expanding nucleus is further supported by the fact that the common adult pattern is almost identical with that of children (Figs. 8 and 9). Two further specimens suggest, however, that there may be important exceptions. Figure 10 shows the navicular of a child aged four in which a single dorsal artery branches and supplies almost the whole nucleus. A few small vessels also penetrate, but take little part in the main anastomotic network. The other anomalous specimen

FIG. 11

Fine-grain radiograph of a decalcified navicular from a boy aged thirteen years. (×2.) A large part of the bone, which now fills the whole specimen, is supplied by a single plantar artery. Other radial vessels have, however, been incorporated and play an important part in nourishing the bone.

(Fig. 11) suggests that a main plantar artery has been responsible for the supply of the whole nucleus up to a fairly late stage of development. Numerous, though short, radial vessels are, however, incorporated into the final bone.

It seems, therefore, that at five years (when Köhler's disease is most common) the ossific nucleus is supplied by five or six arteries which contribute fully to the vascular network within the bone. Alternatively, and less commonly, a single dorsal or plantar artery may be responsible for the nutrition of almost the whole nucleus.

CLINICAL AND RADIOGRAPHIC FEATURES OF KÖHLER'S DISEASE

These features are well known and are confirmed by a study of many series of cases which have been published, the most valuable recent contributions being by Recine (1954), Benedetti and Macconi (1954) and Martinie-Dubousquet (1956). The records of sixty-two patients with Köhler's disease who attended the Wingfield-Morris Orthopaedic Hospital and Nuffield Orthopaedic Centre between 1930 and 1957 have been studied.

The condition is more common in boys than girls: in this series there were forty-nine boys and thirteen girls. The age incidence, indicating the time of onset of symptoms, is of significance: the average age of the forty-nine boys was five years and one month and of the thirteen girls three years and ten months. This is confirmed in other series (Karp 1937, Martinie-Dubousquet 1956). Boys are not only affected more frequently than girls but their symptoms begin at least a year later, and this fact must be explained in any theory of pathogenesis. The suggestion that boys injure themselves more easily is not convincing. In this group only two cases were recorded as affecting both feet, but it is possible that a higher incidence might be found if both feet were radiographed routinely. Martinie-Dubousquet (1956) noted eight bilateral cases out of twenty-four.

The child usually presents with pain and tenderness localised to the region of the navicular, and a limp. In a few cases there may have been an injury but more often than not the history

FIG. 12

Figure 12—Lateral radiograph of a boy aged four years who had pain and limp for the preceding five months. The navicular is flattened, with loss of normal trabecular pattern and areas of increased density. Figure 13—Two years later. The bone is perhaps still slightly flattened but otherwise normal. Growth is not yet complete.

FIG. 13

is vague. Swelling is not uncommon and it was found in nearly half the children in this series. The reaction may be more severe: increased heat was noted in nine cases. The condition apparently is not more common in any particular shape of foot.

Radiographs show that the navicular is altered in shape, size and structure. Köhler (1928) emphasised the increased density and " want of structure " of the bone. Although there are many variations, a study of these cases suggests that there are two different types of radiological abnormality. In the first, which is the more common, the initial radiographs show the navicular to be flattened, as if it had been squashed, with patchy areas of increased density and loss of the normal trabecular pattern (Fig. 12). After two years the process has evolved, the bone being perhaps slightly flattened but otherwise normal (Fig. 13); growth is not yet complete. In the second type early films show the navicular to be of normal shape but uniformly increased in density compared with the other tarsal bones (Fig. 14). Four months later (Fig. 15) the dense bone is partly absorbed. After a further ten months (Fig. 16) all that remains is a faint narrow shadow. Twenty months from the onset (Fig. 17) the bone is beginning to re-form from several small centres of ossification.

A remarkable feature of Köhler's disease is the way in which the navicular is reconstituted to normal. This point is stressed and agreed on by most authors (Köhler 1928, Karp 1937, Benedetti and Macconi 1954, Martinie-Dubousquet 1956). The process may take

six months, but more usually between eighteen months and three years. The only case in the literature in which the changes present in childhood have been shown to persist in any degree into adolescence was published by Brailsford (1939). Twelve patients have been seen ten or more years after the onset, and they all have normal naviculars. There are two patients in whom the last available radiographs show a minor residual deformity of the bone, but it has not been possible to follow these children into adult life. It is probable that most naviculars

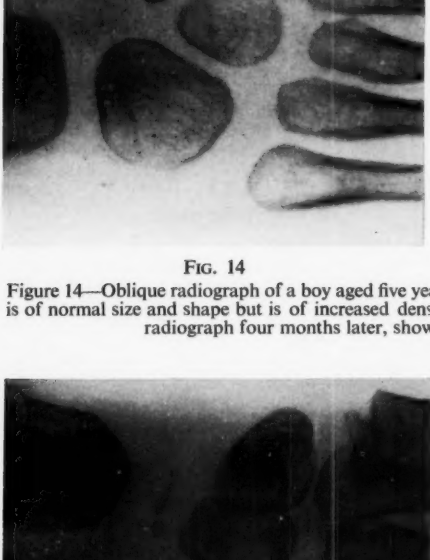

FIG. 14

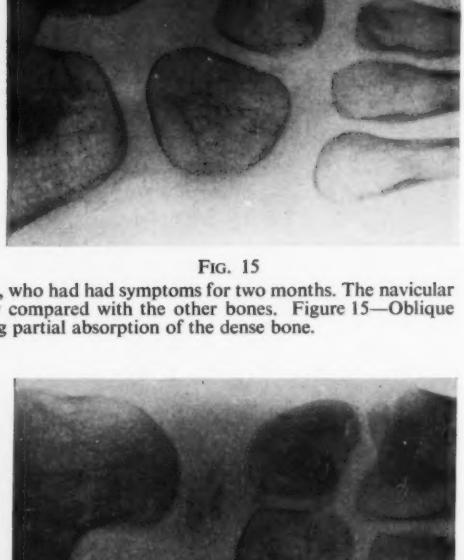

FIG. 15

Figure 14—Oblique radiograph of a boy aged five years, who had had symptoms for two months. The navicular is of normal size and shape but is of increased density compared with the other bones. Figure 15—Oblique radiograph four months later, showing partial absorption of the dense bone.

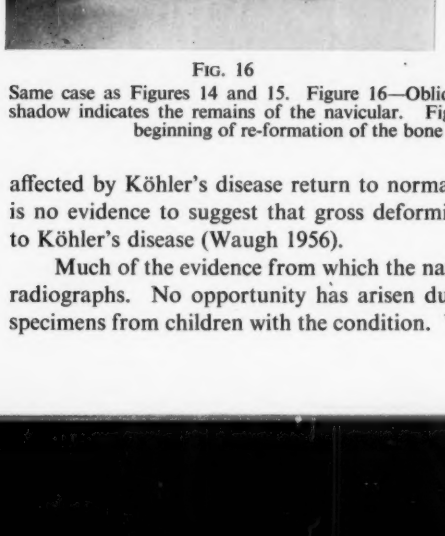

FIG. 16

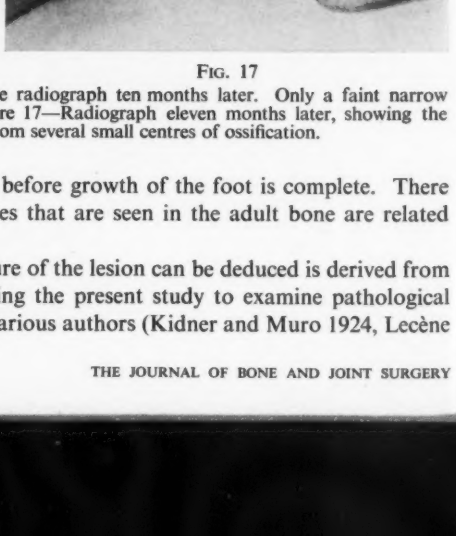

FIG. 17

Same case as Figures 14 and 15. Figure 16—Oblique radiograph ten months later. Only a faint narrow shadow indicates the remains of the navicular. Figure 17—Radiograph eleven months later, showing the beginning of re-formation of the bone from several small centres of ossification.

affected by Köhler's disease return to normal before growth of the foot is complete. There is no evidence to suggest that gross deformities that are seen in the adult bone are related to Köhler's disease (Waugh 1956).

Much of the evidence from which the nature of the lesion can be deduced is derived from radiographs. No opportunity has arisen during the present study to examine pathological specimens from children with the condition. Various authors (Kidner and Muro 1924, Lecène

and Mouchet 1924; Speed 1927; Phemister, Brunschwig and Day 1930; Recine 1954) have described the microscopic appearances of the bone following biopsy or excision of the affected navicular. These usually show scattered areas of necrosis, bone destruction and absorption, but provide little helpful information about the etiology.

DISCUSSION

Many theories have been put forward to explain the nature and cause of Köhler's disease, but none provides a satisfactory answer. Phemister's (1930) evidence of an infective lesion has been discredited. Köhler (1928) himself was convinced that a single injury was not responsible, but he did suggest that the changes might be produced by an immoderate strain acting on a normal navicular for some months at a time, or a continuous normal strain acting on a navicular "weak in development"; he did not, however, pursue this argument further. Nagura and Kosuge (1939) were able to produce a somewhat similar lesion by damaging the cancellous bone of the rabbit's navicular with a sharp instrument, but experimental work of this nature has a limited practical application. The developmental theory is also unsatisfactory: the bone may be normal before the changes appear and thus preclude any primary epiphysial disorder. Fairbank (1957) had never seen changes like those of Köhler's disease in dysplasia epiphysialis multiplex.

Any concept of etiology must explain both abnormal ossification and Köhler's disease, and there is some evidence that both these disorders may have a mechanical basis. The position of the bone in the arch of the foot, and the fact that the navicular is always the last tarsal bone to ossify, suggest that the growing nucleus may be particularly susceptible to the compression forces of weight bearing. No relationship could be established between a child's weight or height and either the time of appearance of the ossific nucleus of the navicular or the development of irregularities in ossification. Similarly, Köhler's disease is no commoner in fat boys than in thin, nor in feet of any particular shape. Although it is disappointing not to be able to demonstrate any direct relationship between the changes and obvious mechanical imbalance, another explanation is possible.

It is reasonable to suppose that the surrounding cartilage can protect the bone from compression when the nucleus first appears. As growth continues, a point may be reached at which the proportion of cartilage to bone is reduced so that the bone begins to take stresses more or less directly. At this stage, which probably occurs between one and two years after the appearance of the ossific centre, the trabeculae become orientated horizontally (as can be seen in the lateral radiographs) to meet the demands of weight bearing.

If the nucleus develops relatively late, say at the age of four years, the critical point (which is probably of short duration) will be reached when the child is heavier and the weight bearing stress is greater than it would be if the nucleus appeared earlier, say at the age of two years. The retarded navicular is delayed in development absolutely in relation to the other tarsal bones and consequently is compressed by the already well ossified talus and cuneiforms. For these reasons a navicular whose nucleus appears late may be subjected to more pressure than its bone structure is able to withstand at a certain period during growth. Abnormalities of ossification may, therefore, be a response of the unprotected growing nucleus to normal stresses of weight bearing. The changes produced vary considerably from minor irregularities to flattening and increased density, and this will depend on the state of the nucleus, the mechanical factors and time over which they act. Increased density can be produced by crowding or increased thickness of trabeculae in response to pressure, or else result from ischaemia, as is likely in the fully developed lesion in Köhler's disease. Changes may be quite asymmetrical in each foot, as is seen in the serial radiographs of normal children. When this is the case, it is usual for the more affected navicular to be the one which appeared later and is the smaller of the two.

Although this theory might account for abnormal ossification, it does not explain how similar changes may be associated with symptoms. The answer may lie in the blood supply of the navicular. It may be suggested that if compression forces pass a certain point the nutrition of the nucleus is likely to be jeopardised. Vessels in the spongy bone may be occluded so that an ischaemic lesion develops. Soeur and de Racker (1952) put forward a similar concept to account for the vascular lesion in Perthes' disease. The production of ischaemia centrally in the ossific nucleus of the navicular seems more acceptable than the idea that it could be caused outside the bone. The navicular, unlike the femoral head at five to six years, has a profuse perichondrial network of vessels, and it is difficult to imagine a peripheral lesion that could cut off the blood supply to the central nucleus. The lesion produced by compression may either involve the vessels in the spongy bone or it may occur at the junction between the newly formed bone and the epiphysial cartilage. There is some evidence that the latter is more likely (Recine 1954).

The two radiographic types of Köhler's disease can be explained by variations in the vascular pattern of the affected bone. In the first, where the navicular is flattened and shows areas of increased density (Fig. 12), the ischaemia is patchy and may be related to a particular sector of the bone. This nucleus is probably penetrated by several vessels (as in Fig. 7) so that the lesion is incomplete. In the second type, which shows at first total increased density (Fig. 14) and is followed by disappearance of the nucleus (Figs. 15 and 16), the ischaemia is more or less complete, suggesting that the bone is largely supplied by a single vessel (as in Fig. 10). The presence of ischaemia in either case will be followed by reactive hyperaemia which will produce local pain, tenderness, swelling and sometimes increased heat. It is not possible to say how long either phase lasts, but this may be related to the vascular characteristics of the bone. There will be considerable variation in any given case; zones of ischaemia and hyperaemia may be present together in any particular navicular.

This theory explains some of the facts that are known about Köhler's disease. The nucleus of the navicular appears on average later in boys than girls, consequently abnormal ossification and Köhler's disease are far more common in boys than girls. This is to be expected when it is appreciated that the retarded navicular is exposed to greater compression than one which ossifies early. Furthermore, the boys in this series were, on average, 2 to 3 lb. heavier than the girls at any given time.

The next feature to be explained is the remarkable capacity that the navicular has for recovery. This is in direct contrast to the femoral head in Perthes' disease, where residual deformities are usual. Two factors may be responsible. First, radiographs show that although the bony nucleus is narrowed, the space between the talus and the cuneiforms is not decreased (this is true in abnormal ossification and in Köhler's disease), and this space is occupied by cartilage. This hypertrophied cartilage may be produced as a response to increased pressure or, more likely, to central bony ischaemia. It re-forms a thick layer of tissue, which can act as a shock absorber, and allows the bony nucleus to develop normally again. Second, and of greater importance, is the radial arrangement of the blood vessels. Even if a single artery supplies nearly the whole of the ossific centre, the perichondrial ring of vessels sends branches towards, if not into, the developing bone. This contrasts with the capital epiphysis of the femur, whose blood supply is limited to two main sources and where the open epiphysial plate is a barrier to revascularisation (Trueta 1957). No such barrier is present in the navicular, and penetration of the central nucleus by the radial vessels is easily possible, so allowing rapid revascularisation and reconstitution of the bone under the protection of the surrounding cartilage. In the less common type of Köhler's disease, the re-formation of the nucleus from a series of scattered points of new bone formation (Fig. 17) suggests that this process takes place initially at the endings of several vessels.

SUMMARY

1. Serial radiographs of fifty-two normal children's feet, taken at six-monthly intervals between two and five years, have been reviewed.
2. Twenty-one naviculars have been injected post-mortem and the vascularisation of the growing bone investigated.
3. The records of sixty-two children with a diagnosis of Köhler's disease have been studied.
4. It is submitted that abnormal ossification results from compression of the bony nucleus at a critical phase during growth of a navicular bone whose appearance is delayed.
5. Symptoms in Köhler's disease are related to further compression which produces vascular changes in the bony nucleus. Consequent ischaemia is followed by hyperaemia which produces local pain, tenderness and swelling.
6. Two radiographic types of Köhler's disease are described and attributed to variations in the basic vascular pattern of the affected bone.
7. The usual complete recovery of the navicular is ascribed in part to the basic arrangement of numerous radially penetrating vessels.

My thanks are due to Professor J. Trueta, who has given me most valuable advice and constant encouragement throughout the time spent in this investigation. I am grateful to the surgeons of the Nuffield Orthopaedic Centre for permission to review their cases, and also to Dr F. H. Kemp and Dr Alice Stewart for allowing me access to the records of the Institute of Social Medicine, University of Oxford.

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THE MECHANICAL PROBLEM OF THE ARTIFICIAL HIP

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"Just as the basic idea of Lane plates lived on by changing towards the more natural, so will arthroplasties involving interposition of inert materials survive only if they also tend toward the more natural." Bryan McFarland, 1954.

The complete solution to the problem of arthroplasty will be found only when we can provide our patients with new hips either made of, or able to unite with, living bone. Although it is by no means certain that such biomechanical synthesis is possible, this remains the goal for research, and unsuccessful attempts at welding artificial femoral heads and sockets in place by means of fast-setting dental acrylic have in fact been made by Haboush (1953). A more promising field lies in the covering of raw bony surfaces by grafts of articular cartilage which, nourished by synovial fluid, do in fact survive readily along with a thin plate of subjacent bone (Gallie 1956*b*). Unfortunately in the hip survival of the cartilage is nullified by changes due to avascularity or disease in the underlying femoral head, and it is perhaps because this abnormal bone is not removed that " cartilage-cup arthroplasty " has not been more successful. Some modification of it may provide the answer we are seeking.

Meanwhile, when in 1939 Smith-Petersen produced the first really practical artificial hip by means of a Vitallium cup, a strong fillip was given to the search. The articular surfaces, remodelled, with the cup between them, produced a brand new cartilaginous lining to the joint in response to the frictional and weight-bearing stresses on each side of the mould (Smith-Petersen 1939). As a result, the complete replacement of the femoral head by Judet followed as a matter of course.

When it became apparent that these acrylic replacements were unable to stay the pace of life in the human body for more than a few years there descended a fog of pessimism dense enough to obscure for a time the brilliance of many of the results during the earlier post-operative periods. As an example, Charnley (1956) considered mobility in the reconstructed hip an " unattainable ideal," and any form of replacement arthroplasty " doomed to failure " if only because of the physical differences between living tissue and inert substances. But whereas a few years ago the case for arthroplasty rested solely upon the fact that every other hip reconstruction was an admission of defeat, that case must now also rest upon the achievement of numerous successes with inert appliances.

Denham and Law (1957), in a recent analysis of two hundred cup and replacement arthroplasties, claimed four outstanding factors which, taken together, can be depended upon to produce—in eighteen months to two years—a successful and permanent cup arthroplasty. These are the use of a wide-mouthed cup of the Smith-Petersen type, an adequately excavated acetabular roof, intact abductor insertions and freedom from post-operative complications. But they have not found a dependable answer to the problem of those patients whose femoral heads are so unserviceable that they demand resection and replacement, or those whose age or general condition make them unsuitable for any method which will not allow early post-operative weight bearing on the new joint.

For an artificial hip, held in position by mechanical forces, there are two principal requirements: suitable materials and sound mechanics. The former will be discussed briefly later on; as to the latter, there is now strong evidence to support the contention that a prosthesis remains successful just so long as its mechanical fixation remains sound; so the next step in the evolution of hip arthroplasty ought logically to lie in the field which is most

within our compass—that of design. We must aim, as an engineering friend remarked in Irish vein, at putting back into the bone the stresses already there, by placing them along the lines already adapted for them. And we must also see that we do not create new ones.

THE UPPER END OF THE FEMUR

Architecture—The lines of stress which normally conduct the great forces of weight and movement through the femoral head and neck demand first consideration if it is accepted

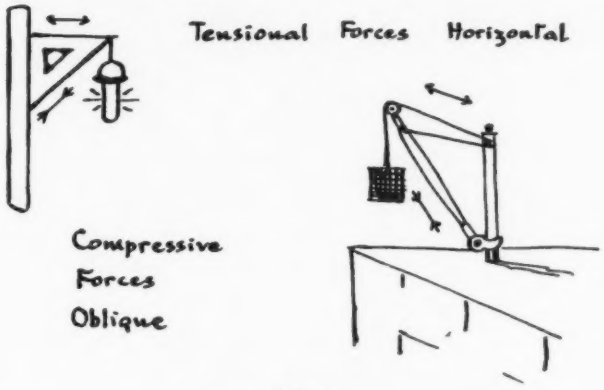


FIG. 1
The mechanical stresses in the upper end of the femur have been compared to those of a lamp bracket and a crane.

that the primary function of a mechanically sound hip is to transmit those forces smoothly between acetabulum and femoral shaft. The more a prosthesis can be made to lie in balance with these natural lines of stress above and below it, the less intrinsic strength it will need—in other words the more it can conduct the less it will have to withstand.

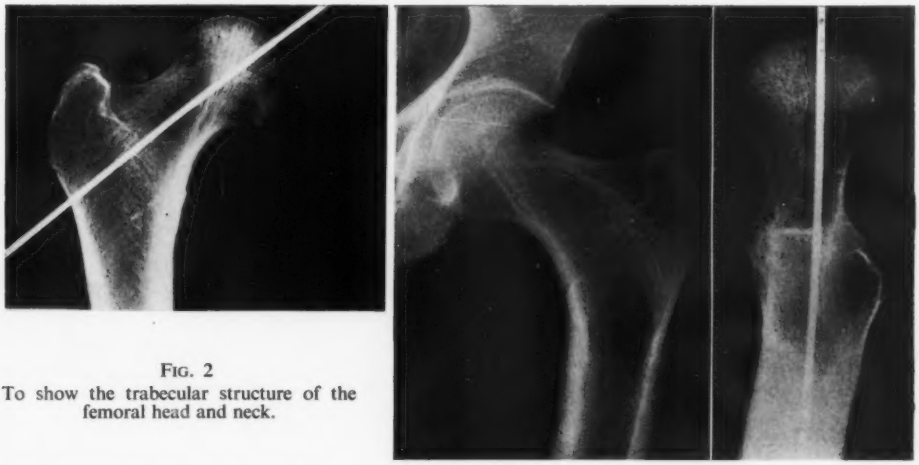


FIG. 2
To show the trabecular structure of the femoral head and neck.

The internal architecture of the upper end of the femur consists of a series of Gothic arches, converging towards the head and with pillars resting upon the diaphysial cylinder. Besides these cancellous arches there is also that remarkable internal spur of cortical bone,

the calcar femorale, best developed at trochanteric level and representing an upward prolongation of the diaphysial cortex into the interior of the neck through the lesser trochanter (Debeyre and Doliveux 1955).

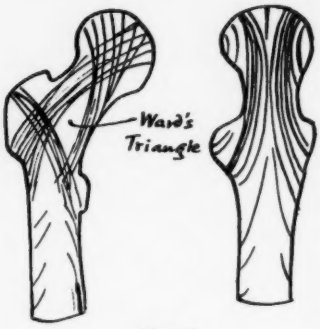


FIG. 3
Ward's triangle.

The cancellous trabeculae forming the arches are arranged in two main columns running up the superior and inferior aspects of the neck to intersect and decussate in a dense central wedge below the head, and thence fan out into a series of bony plates which meet the articular surface at right angles to its tangents throughout. This system was likened by Ward in 1838 to a lamp bracket, and by von Meyer (1867) to a crane (Figs. 1 to 3). It is apparent that any force applied to the femoral head is at once transmitted to the central wedge, and thence to the cylindrical diaphysis—the crane post—by means of the superior (tensional) trabeculae working reciprocally in conjunction with the inferior (compressive) ones. In a lateral view it will be seen that only a few of the lamellae on the anterior and posterior aspects appear to join the decussations in the central wedge, the majority distributing themselves so as to buttress the key area by arching their backs against it.

Between the two columns lies a structurally weak area of less dense bone, based upon a third column stretched between the trochanters. This is Ward's triangle, which in the analogy of the lamp bracket represents the cut-out centre of a plate. This area, through which passes the central axis of the neck and which must clearly have a bearing upon the etiology of fractures, will provide no secure anchorage for nail or prosthetic stem.

The trabecular pattern is explained in terms of Wolff's law, which states that the form of bone is produced in response to the stresses encountered; or, more simply, that the bony trabeculations follow the directions of the principal stresses (Haboush 1953). The classical example quoted to support this is the sloth's femur, devoid of any trace of trabecular differentiation since he lives upside-down, hanging from a tree. It is interesting that as early as 1931 Campbell, delivering the Robert Jones lecture at the New York Hospital for Joint Diseases on the subject of arthroplasty, showed radiographic evidence of restoration of bony structure and trabecular rearrangement " conforming to the lines of stress in the reconstructed joint." The architecture may thus be said to arise from a combination of all the principal stresses about a neutral axis which becomes their resultant, so that whereas the mechanical axis of the femur is said to be a line between the head and the intercondylar notch, it is around the anatomical axis in the centre of the bone that the forces are actually carried.

It follows from this that in coxa vara the anatomical axis shifts downwards, and under the influence of increased tensile stress the superior trabeculae hypertrophy. In coxa valga the shift is upward and the compression trabeculae bear the greater brunt. One may readily see this when watching a crane in action, and it has also been demonstrated by photo-elastic observance of the structural changes occurring in an acrylic model, which under stress becomes birefringent so that its molecules are rearranged according to lines of force visible under polarised light (Figs. 4 and 5).

All the evidence seems to confirm that Wolff's law and the theories of Ward and von Meyer hold broadly true for the upper end of the femur. The actual nature of the process whereby Wolff's law is put into effect has also received recent attention from Scott (1957) who conceived the mechanical basis of bone formation as intermittent trabecular pressure and tension with elastic recoil. Further small-scale detail is to be expected with the use of such methods as microradiography and the electron microscope.

In its crane-like structure lies the key to the meaning and purpose of the femoral neck. Just as a crane is designed to bring the load over the work, so the femoral neck is designed to place the erect human form upon the broadest possible base. In modern times there has been a tendency to decry the femoral neck as an area of inherent potential weakness—the

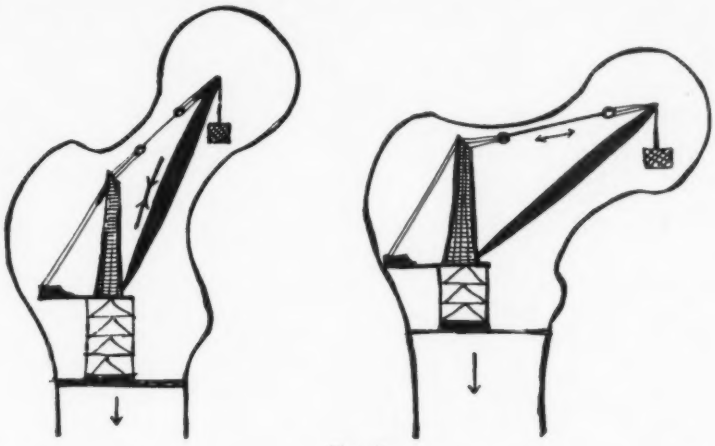


FIG. 4
Scale drawing of movable-jib crane to illustrate the forces in coxa vara and coxa valga.

French surgeons for instance have dubbed it the " porte-à-faux " of weight bearing—but I believe it is only when the architecture becomes abnormal that the neck becomes a source of weakness.

FIG. 5

FIG. 6

Figure 5—Appearances of models undergoing constant pressure seen with polarised light. (After Pauwels, reproduced by Debeyre and Doliveux 1955).
Figure 6—Arteries of femoral head and neck. (After Judet *et al.* 1955.)

To examine its mechanics more closely: the neck consists of an external cortical component, analogous to a fixed-jib crane, supported by an internal cancellous strutting system made up of the decussating trabecular columns. According to Tobin (1955), weight bearing in the upper end of the femur is predominantly by cancellous bone, which is of equal

strength—weight for weight—to compact bone. However, as Charnley, Blockey and Purser (1957) recently pointed out, the cancellous system does not commonly persist throughout life, the femoral neck in the elderly being no more than a hollow tube filled with fatty marrow. When this occurs the normal crane system becomes reversed, so that the stresses passing through the lower half of the head (which is normally held up by the tension of the superior trabecular column) are converted to shearing ones, contributing to the liability of fracture.

It is plain, therefore, that the cancellous trabeculae cannot be relied upon to support an artificial hip. On the other hand it may be possible to replace these columns, and if so, their own structural pattern should provide the soundest guide to the design of the replacement.

Blood supply—This is outside the scope of the present paper, but since the problem is so essentially biomechanical in kind, and any prosthesis so dependent upon the living tissue around it, a few salient facts will be recounted here. The work of Trueta and Harrison (1953) and that of Judet *et al.* (1955) is well known and certain broad conclusions have been made.

The blood supply derives mainly from an anastomosis in the trochanteric fossa of the circumflex, obturator and inferior gluteal arteries. Thence vessels run proximally in the capsular attachments, branches entering the neck by perforating the cortex. The common pattern is shown in Figure 6, and it is apparent that the superior group of vessels predominates. These are the lateral epiphysial arteries of Trueta and Harrison, which terminate by entering the bone at the cervico-capital junction. The arteries of the superior group supply nearly all the cancellous bone of the neck, and in replacement arthroplasty the line of section should therefore be planned to spare them whenever possible.

Although there is a free anastomosis between all the arteries around the neck, as well as between intra-osseous and extra-osseous vessels, the direction of the intracervical vessels, once they have entered the bone, is mostly downwards towards the diaphysis. The diaphysial arteries, on the contrary, do not appear to make a similar contribution to the nourishment of the neck or head, as one might have expected they would.

Except at the epiphysial areas of the head and greater trochanter the vascular pattern is unrelated to the trabecular pattern.

Judet (1955) and his colleagues found that the blood supply of both head and neck was largely destroyed by cutting the femoral capsular attachments, whereas a less complete resection jeopardised the capital but left intact the cervical flow—a point that bears on technique in both cup arthroplasty and replacement arthroplasty.

Reaming the cervical stump to make a smooth bed for a prosthesis, and drilling the neck for the stem, have been found to cause extensive destruction respectively of extra-osseous and intra-osseous vessels. Laing and Ross (1952) demonstrated necrosis beneath a prosthetic stem two weeks after operation, and Judet found similar changes later under the weight-bearing segment of the rim. However, the fourteen-day findings of Laing and Ross should be treated with reserve because, as Collins (1954) remarked, considerable necrosis occurs normally after fracture or section of a bone, as a natural prelude to resorption and regeneration. In another femur examined two years after a Judet replacement arthroplasty it was found that good revascularisation had occurred, though with a pattern that bore no relation to the normal. Judet *et al.* (1955) considered that stabilisation of a prosthesis—clinically and radiologically evident—follows this revascularisation, and he stressed the potential danger of weight bearing before the process is complete. He pointed out that the area of cervical stump to receive the main brunt of the weight is the very area where revascularisation has to take place after operation.

Nevertheless good results—some promising to endure—have now been reported in replacement arthroplasty with 'very early post-operative weight bearing (Moore 1957, Stinchfield *et al.* 1957).

THE MECHANICS OF WEIGHT BEARING AT THE HIP

The four main stresses that fall upon the upper end of the femur are tensile, compressive, bending and shearing. Some rotational strain may also be thrown on the neck during flexion and extension, independently of weight bearing. Trabecular formation, according to Haboush, occurs only in response to stresses that are either tensile or compressive.

Figure 7 illustrates the well known static mechanics of standing on one leg. Alterations in body weight are thrice multiplied within the hip joint, and it seems probable that against such loads the difference between a prosthesis in steel or acrylic affects the hip no more than changing to a lighter or heavier overcoat.

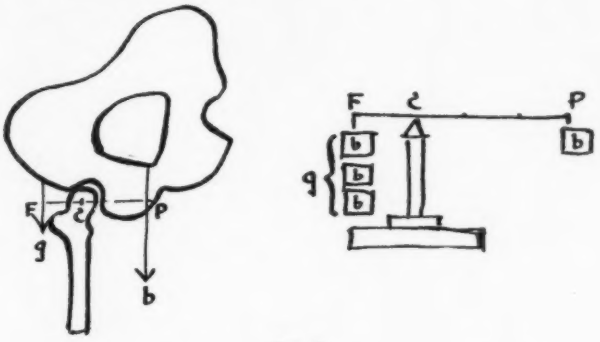


FIG. 7

Weight bearing in one leg: b = body weight; g = gluteal pull.
If PC = 3FC, then $g = 3b$. Then total load at C = $g + b = 4b$.

There are several ways by which the hip may be relieved of its burdens. First, by leaning towards the weight-bearing hip; this is the attitude of the hop-scotch player, and it reduces the discrepancy in lever length by bringing the centre of gravity nearer the head. Secondly, by using a walking-stick in the opposite hand, which Blount (1956) computed to relieve the joint of one-third of its load. Thirdly, by moving the greater trochanter farther outwards from the head, as occurs in coxa vara and in lengthening of the femoral neck. (It is important to see that although these conditions relieve the femoral head, they actually surcharge the neck. The reverse holds good for coxa valga and neck shortening.) Fourthly, by bringing the head nearer the midline—as by deepening the acetabulum—in order to equalise the levers. Denham (1956) calculated that a medial displacement of one inch ought theoretically to relieve the hip of half a hundredweight. Fifthly, by transplantation of the abductor insertions farther down the shaft, which will tighten them up and increase the length of their working lever, but in practice has proved a disappointing operation. Lastly, by moving the shaft inwards by displacement osteotomy until some of the weight is borne directly upon a new pelvic fulcrum farther medially. Unless displacement is sufficient to do this, as McMurray (1939) stressed, the osteotomy will have no mechanical effect, whatever its biological ones.

The femoral head, as already seen, is structurally adapted to receive weight at right angles to the whole of its articular surface; but such an arrangement will work only if there is perfect fit between the joint components. Debeyre and Doliveux (1955) estimated the pressure on a normal femoral head at 2 kilograms per square centimetre, and they stated that in an ill fitting joint this figure may be multiplied forty times, especially when a conical head makes with the acetabulum what they term " contact polaire." Furthermore, even in the normal hip the load is not evenly distributed. Lloyd-Roberts (1955), by intra-articular injection of wax, demonstrated the " pressure area," greatest in extension (the position of maximum stability) but always less than half the articular surface area, and diminishing as the joint moves away

from the extended position. These observations give point to the second major effect claimed by McMurray (1939) for displacement osteotomy, namely alteration of the pressure area through the inward rotation of the upper fragment which occurs post-operatively owing to muscle pull—an effect which of course can in no wise take place if internal fixation is used.

Besides these static loads, it is equally necessary, and far more difficult, to assess the dynamic stresses accompanying movement, controlled as they are by endless combinations of

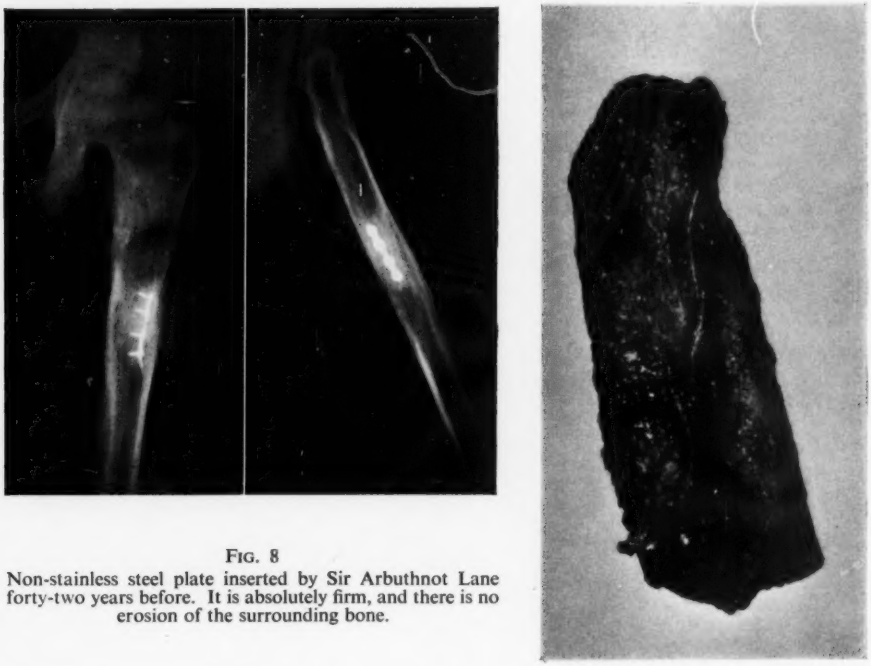


FIG. 8
Non-stainless steel plate inserted by Sir Arbuthnot Lane forty-two years before. It is absolutely firm, and there is no erosion of the surrounding bone.

co-ordinated—or unco-ordinated—muscle action. The presence or absence of limp, to take the most obvious, is certainly a major factor in the behaviour of the natural or artificial hip, whether due to gluteal insufficiency, to a loose prosthesis or simply to pain. What is lacking is a quantitative method of measuring the forces concerned. Anyone who doubts the measure of uncertainty which exists about muscle action should read Henry's (1957) account of gluteus maximus, which, quoting a description of the muscle by Leonardo da Vinci (1498), debunks nearly every function since attributed to it.

Thus to consider the hip joint merely in terms of its bony components, as a ball and socket, is a dangerous over-simplification. Nevertheless it is this very complexity of the functional anatomy that casts us back upon the bony architectural detail designed to serve its needs.

PROSTHETIC MATERIALS

Great progress has been made in finding materials which, though lacking the supreme slipperiness of articular cartilage (Charnley 1955), are tolerated by the body for long periods. Figure 8 shows the radiographic and photographic appearances of a mild-steel plate inserted by Sir Arbuthnot Lane forty-two years ago to immobilise a birth fracture, and recently removed by the author. The metal was absolutely firm in the bone, and Dr Scales, who kindly examined the materials microscopically, found no unfavourable bony reaction despite considerable surface corrosion of the plate and screws. This specimen illustrates the long-term

answer to corrosion—that once the appliance becomes surface oxidised the process automatically ceases; the short-term answer is removal of the appliance. But with the development of non-ferrous alloys such as Vitallium and the clinical trial of the element Titanium (Leventhal 1951), substances reported to be totally free from foreign-body reaction, corrosion ceases to be a problem and we are left free to consider the mechanical effects of an inert prosthesis.

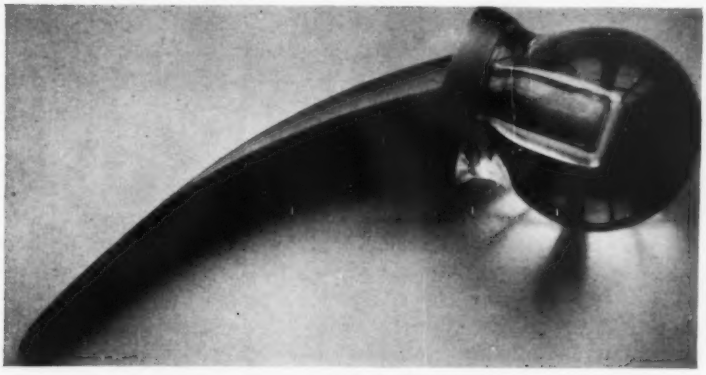


FIG. 9
Leakage of blood between acrylic and metal parts.

But first it is necessary to be sure that the inert material is of adequate strength for the job. Bell (1957) described bone as " nearly as strong as steel and much more elastic," with a bending stress of 35,000 lb. per square inch—three and a half times that of hard wood. Martz (1956), who tested a number of internal prosthetic appliances and found them in every case far weaker than normal bone, also pointed out that the " fatigue-strength " of surgical steels is only equal to half their ultimate strength on the bench, and that the rest given to a prosthesis while the patient is asleep will not suffice to prevent fatigue fracture. We must therefore guard against inserting an appliance which—however well designed—is yet bound to succumb to fatigue if the patient lives long enough. Research on materials continues, and in the United States standards are being developed and applied to prosthetic appliances so that the surgeon may know precisely what strength of material he is using (Scales 1956).

Figure 9 illustrates one of the drawbacks of a composite prosthesis, in this case steel and acrylic. Staining can be seen where seepage of blood has occurred between the component parts.

THE EFFECTS OF AN INERT APPLIANCE IN THE UPPER END OF THE FEMUR

When a prosthesis is inserted into bone there occurs, depending upon the mechanical conditions, one of two quite contrary and opposing reactions. The first may be called remodelling, and represents an active, dynamic response in accordance with Wolff's law. This favourable reaction continues as long as a prosthesis remains firm in its bed. The second, which is really pressure necrosis, occurs when the strain on the bone—either because of frictional movement or bad positioning relative to the forces encountered—reaches a figure, as yet unknown, where remodelling ceases to take place.

Collins (1953, 1954) investigated the reactions and histological changes around Smith-Petersen nails, where weight-bearing forces were not involved, and Judet prostheses, where they were. His findings, as well as the experiences of Moore (1957) and Lippmann (1957), establish that the natural reaction of trabecular hypertrophy in response to Wolff's law is essential for any successful arthroplasty, and does in fact occur about a prosthesis lying in balance with the

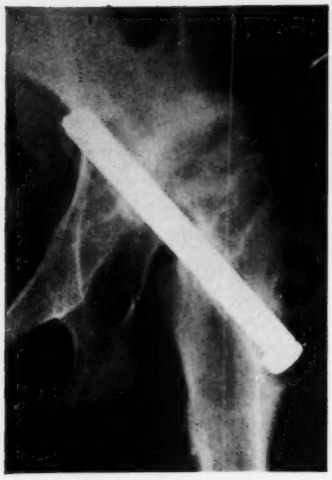


FIG. 10
Encapsulation of a foreign body by cortical bone.

natural forces; whereas pressure necrosis, "l'arthrose sous-prosthétique" as the French surgeons call it, represents an unnatural response to a foreign body placed athwart those forces so that the bone can no longer maintain equilibrium with the new conditions.

Radiologically it is not always easy to distinguish the early stages of these two reactions, because both may show increased density, and because all too frequently an early favourable response may change almost imperceptibly to an unfavourable one. However, the beginnings of clinical deterioration can be depended upon to coincide with the appearance of unfavourable radiographic changes.

At its first entry a nail or prosthetic stem shatters a few trabeculae, causing slight intra-osseous haemorrhage. During the repair of this damage the foreign body becomes encapsulated, first by fibrin and then by fibrous tissue in which bone is later deposited parallel to it. In twenty weeks a complete bony shell is present (Fig. 10); at two and a half years plates of cortical bone supported by a cancellous framework are found, and at five years fully developed Haversian systems. A Smith-Petersen nail examined five years after insertion lay tightly within the bone, its channel lined with a periosteal envelope half a millimetre thick, supported by fully vascularised bony plates parallel to its vanes and as dense as the normal cortex of the femoral neck; bone had also grown into the cannula for a distance of two

FIG. 11
Replacement arthroplasty three and a half years old, in which the clinical result is virtually a normal hip.

millimetres (Collins 1953, 1954). Figure 11 shows a Judet arthroplasty three and a half years old which illustrates this normal response radiologically, and in which at the time the clinical result was virtually a normal hip.

The mechanical conditions that tend to perpetuate or to undo this natural bone reaction will now be considered in relation to artificial hips.

CUP AND REPLACEMENT ARTHROPLASTY—GENERAL CONSIDERATIONS

A cup satisfies the mechanical ideal of conducting rather than trying to absorb the stresses, because weight bearing remains on the femoral head as in the natural hip. And it liberates itself from the strains of motion by allowing free movement on either side of it. There is nothing to loosen because it is already loose. It is not surprising that breakage, though occasionally reported, is rare.

Smith-Petersen soon discovered that the bony surfaces in contact with a cup became covered with fibrocartilage, approximating in some areas to hyaline cartilage. Further careful work by Gibson and Williams (1951) confirmed this, the authors concluding that " tissue form and cellular type correspond to functional demands and that for the reproduction of articular cartilage compression plus gliding movement are a necessary combined stimulus."

This early work defines the essential object of cup arthroplasty, which is to promote the formation of a new joint by the body—not to provide a ready-made one as in replacement arthroplasty. And besides this difference of aim, the indications and limitations of the two methods also differ correspondingly, so that it is just to contrast rather than to compare them with each other.

Denham and Law's (1957) review, as well as the recently published results of Moore (1957), Lippman (1957) and Stinchfield *et al.* (1957), have enabled us to judge how far these original concepts of the cup and of the replacement prosthesis can be translated into clinical language. For each method, when well executed, two broad conclusions emerge from the findings: 1) that for cup arthroplasty a period of at least eighteen months is required before the new joint will function properly, but that once satisfactory it may be expected to remain so; and 2) that for replacement arthroplasty the result is a functioning joint which can be used for weight bearing in the immediate post-operative period, but that its liability to mechanical failure in the course of time is far greater. Thus the clinical findings vindicate the ideas behind the two methods: the cup, free from mechanical strain, basically dependent upon the biological response of the surrounding bones; the replacement arthroplasty upon sound mechanics and secure fixation.

From the mechanical standpoint conservation of the head is vastly preferable to removal. The great forces of weight and movement are concentrated and balanced in the head, which acts both as hub of flywheel and pinnacle of support, so that the more it can be preserved the more benefit will be retained from its specialised structure and supreme concentration of stabilised forces.

But the limitations of cup arthroplasty are determined by the condition of the head. If the latter has been badly enough damaged by trauma or disease it ceases to be a mechanical asset and becomes a biological liability. The advantage of replacement arthroplasty is that, having removed the pathological area, one has to deal with the constant pattern of normal anatomy instead of the inconstant pattern of disease. Its disadvantage is that the pulley and working stock of the femoral crane are sacrificed. Thus the mechanical and biological factors work in opposite directions in the two types of arthroplasty.

THE SMITH-PETERSEN AND CRAWFORD ADAMS CUPS

The Smith-Petersen cup, even when well fitted after reconstruction of both joint surfaces, is liable to move from one eccentric position to another (Fig. 12). Because of this the concentric cup was designed by Adams (Fig. 13) and is possibly the only artificial hip which is free from mechanical objection. Anyone who has used it must have been impressed by watching the movement of this cup after insertion—during flexion and extension the head rotating axially within the cup, while during all other movements cup and head move together as a single

member. This mechanical excellence produced, as expected, better short-term results, but over longer periods they disappointingly evened out with Smith-Petersen's. Adams (1955) attributed this to inadequate blood supply to the femoral head, and Denham (1956) reported

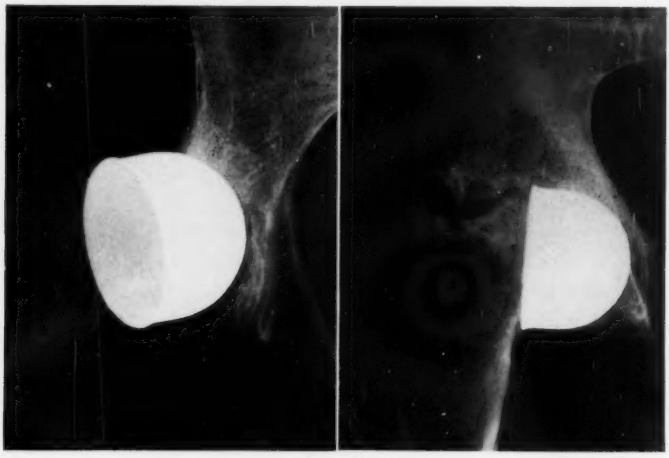


FIG. 12
Eccentric movement of a loosely fitting cup.

cases of fracture of the femoral stump under the tight-fitting cervical part of the prosthesis. He concluded that a loose cup with a wide mouth is safest—a point that supports Judet's work on the ill effects of neck reaming. Thus the mechanical assets of the Adams cup have

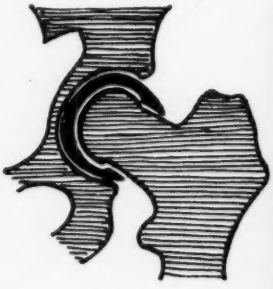


FIG. 13
The thick-walled cup of Adams ensures concentric movement of the femoral head relative to the acetabulum.

been obtained at the expense of biological ones; yet the fact that the speed of post-operative recovery has been found equal to that of the Judet prosthesis is further evidence that in the early stages of any arthroplasty the result depends predominantly on the mechanical conditions.

THE JUDET PROSTHESIS

It was the observation of the relief of pain after removal of the osteoarthritic head in Whitman's operation that led Judet and Judet (1950) to devise the prosthesis which put

replacement arthroplasty first upon the orthopaedic map. Their view of the head as the main source of coxalgia is reflected in their refusal to resect the capsule at operation. This is at variance with the opinion and practice of many British surgeons, but is supported by Stinchfield (1957), in whose series capsulectomy made " little or no difference " in cases of fresh fracture, avascular necrosis or osteoarthritis, though it was considered to have improved the results in patients with non-union. The argument remains unsettled. Although Lloyd-Roberts (1955) has produced evidence of pain of capsular origin, there is as yet no convincing explanation as to why an osteotomy below the hip will generally relieve coxalgia more completely than an arthroplasty with capsular resection, nor of Denham and Law's observation that trochanteric osteotomy appears to be of itself a cause of pain. Here, however, it is the mechanical properties of the prosthesis which are under consideration.

As already seen, it is not surprising that the single articulation provided by a newly fixed prosthesis functions at first much better than a cup which at the same stage can claim to be little else than a loose body in the hip joint. It is equally certain that the clinical deterioration of a once-successful Judet arthroplasty is the direct accompaniment and result of its failure to retain firm fixation in the bone. This painful fact has been observed too many times of recent years for it to be obscured by Denham's suggestion that an adequate abductor mechanism is more important than a completely firm prosthesis, though both must be considered essential factors for clinical success.

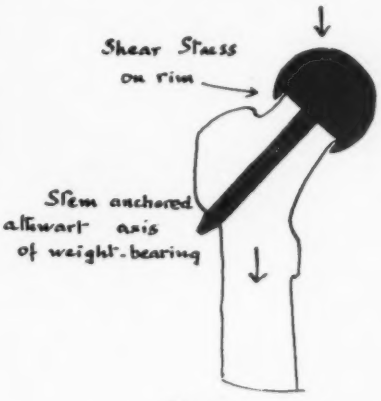


FIG. 14
Diagram showing the mechanics of the original Judet prosthesis.

The weight-bearing forces that mainly affect this prosthesis (Fig. 14) are shearing ones, which act between head and stem and are resisted by the superior part of the rim, and bending ones, which act on the stem and are increased by driving the distal end across the weight-bearing axis into the lateral cortex, and greatly increased if the superior rim gives way. Tensile and compressive forces, magnified respectively in proportion to horizontal or vertical lie, also affect the stem, though less severely. Compression forces pass through the substance of the head, as in any prosthesis. Rotation strain will occur only if articular movement is not free, because the stem does not cross the axis of rotation by going down the shaft.

Figure 15 illustrates the familiar triple sequence of mechanical failure: rocking of the stem with widening of its canal, breakage of the superior rim and finally breakage of the stem; and it is exactly what one would expect from the interplay of forces. It will be seen that the portion of broken rim corresponds accurately to the characteristic flattened facet produced by weight bearing on the superior part of the head. The presence of the facet also illustrates that this prosthesis has been adequately anchored against torsional strain, for had any marked degree of axial rotation occurred the facet would either not have appeared at all or else would have occupied a much larger area (Fig. 16). In the former specimen the facet occupies rather more than one-third of the head—only a slightly higher proportion than the static " pressure area " on the natural head already referred to and described by Lloyd-Roberts (*loc. cit.*). That the mechanically weak axle-brake provided by the flutings of a Judet stem, insecurely anchored in Ward's triangle, can in fact prevent rotation suggests again that these strains are slight when the stem lies wholly within the neutral axis of the neck.

Judet and Judet always intended the stem to penetrate the outer cortex, so as to direct the appliance constantly towards a fixed point, and for further control of rotation. But there are serious mechanical objections. The axis of weight bearing is crossed and the bending

moment on the stem—now anchored at points on either side of it—is greatly increased, especially with its centre lying almost unsupported in the empty spaces of Ward's triangle. Moreover, Haboush (1953) has shown that the stress-concentration at the edges of a cortical perforation will be many times greater than elsewhere. It is interesting that in Buxton and

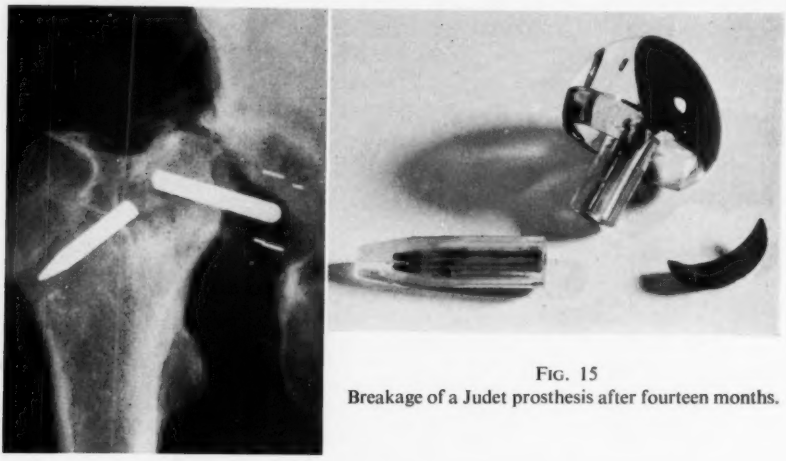


FIG. 15
Breakage of a Judet prosthesis after fourteen months.

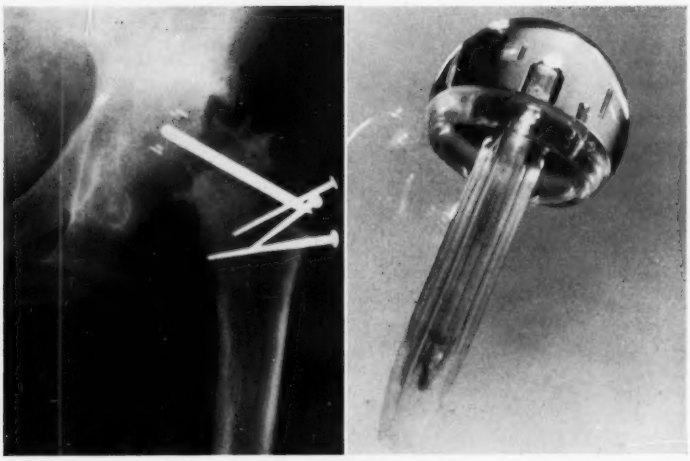


FIG. 16
A four-year-old arthroplasty in a fifteen-stone man who had a gross Trendelenburg "dip" from the earliest days after operation. Loosening with free rotation of the stem occurred before a facet had time to develop on the weight-bearing area, and the prosthesis, further relieved from pressure by the painful limp, has remained in mint condition.

Waugh's (1954) cases shorter stems were used so as not to penetrate the cortex. Though no comparisons have been made it may be significant that in this series a high proportion of favourable bone reactions were observed radiologically.

The intrinsic strength of a Judet head in fresh bone was found by Debeyre and Doliveux (*loc. cit.*) to be just about half that of an intact femoral head, yet despite this the appliance has shown itself able to survive weight bearing so long as its fixation remains firm. Loosening,

however, produces additional strains which prove fatal to it, and as Denham and Law's analysis shows, its breakdown occurs most rapidly when the result of operation is good and the patient strong and active. The mechanical failure of the Judet hip may be summarised by saying that breakage occurs not so much because it is bearing the patient's weight as because its axis runs counter to weight-bearing forces which inexorably loosen it.

These drawbacks led Judet and Judet to introduce a modified prosthesis (Fig. 17). The rim has been removed, to avoid reaming, and weight bearing is transferred to a flat surface obtained by cutting the head obliquely at 60 degrees to the neck. When the neck-shaft angle is 125 degrees this head is inclined at 25 degrees to the horizontal so that its weight-bearing forces lie almost entirely in the direction of the compressive trabeculae. The eccentric stem still crosses the axis of weight bearing though the strains must be much reduced, and it still

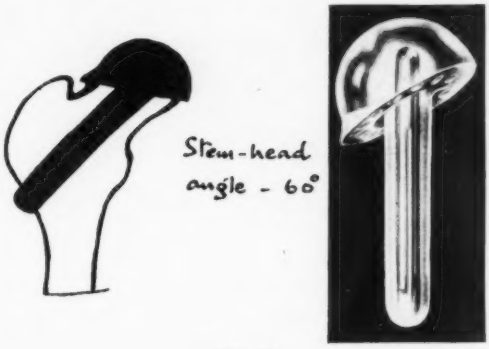


FIG. 17
Modified Judet prosthesis.

runs through the middle of Ward's triangle. The greater trochanter and the superior column of trabeculae are not utilised by this appliance. A brief account of results with this prosthesis has been published (Judet 1957). Clinical successes are reported as 72 per cent, against 67 per cent with the original type, and there was only a single case of broken prosthesis.

Following the breakages of prostheses of the Judet type there grew up, especially in America, a variety of more massive prostheses. In 1954 Shepherd reported thirty-seven in current American use, and in Eürope there developed a similar tendency towards greater resection of neck and deeper penetration of shaft. On mechanical grounds, however, there is reason to doubt whether these bigger and heavier prostheses are likely to prove better ones.

INTRAMEDULLARY PROSTHESES

The first trend that became evident was to devise appliances with stems curved to follow the weight-bearing axis into the shaft. These are open to criticism on the ground that their stems, though soundly placed for weight bearing, lie athwart the rotational axis so that during flexion and extension torsional strain occurs at the junction of neck and prosthesis. Figure 18 illustrates torsional effect on a hip of this type, which has dislocated and rotated nearly 180 degrees within the femoral shaft. Figure 19 illustrates four of the various ways in which this vulnerability to torsional stress has been overcome, though always with an increase of bulk or complexity.

The Merle d'Aubigné prosthesis demands sacrifice of the whole femoral head and neck, and its stem penetrates almost to the knee. It has the advantage of resting upon the best vascularised and most resistant part of the bone. Its weight-bearing surface is flat and its area distribution maximal; thus in one sense its size is its principal quality. Merle d'Aubigné

FIG. 18
Dislocation of an intramedullary prosthesis in consequence of torsional strain.

(1954) emphasised restoration of normal neck length and when necessary correction of anteversion. It may be commented that good results can occur in arthroplasty without full restoration of neck length, just as there may be good function in the natural hip when the neck is shortened by injury or disease. Neck restoration, though clearly important and advisable whenever possible, is not one of the four vital factors found by Denham and Law to be essential for success. The retention of hip movement after " central dislocation " may be further evidence on this point.

In face of the clinical results, some of over five years duration, recently published by Moore (1957) and Lippmann (1957), it may seem presumptuous to criticise the method of

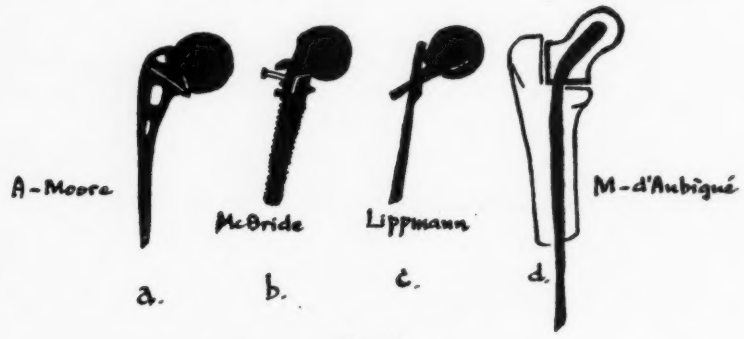


FIG. 19
Four types of intramedullary prosthesis.

either on theoretical grounds. In 153 operations Moore had not a single post-operative dislocation, despite early walking. Lippmann, whose prosthesis incorporates the unique feature of a free-running artificial joint for the head, reported ten of his twenty-seven patients without limp—an improvement in this respect on Moore's figures which showed some degree of limp in all but six out of fifty-five patients.

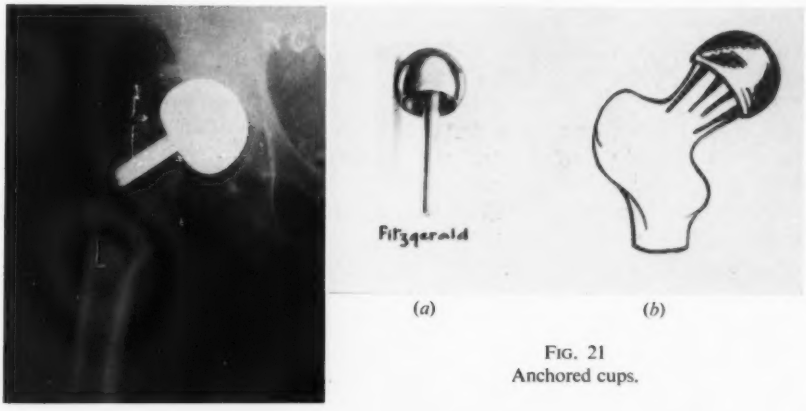
But once any prosthesis leaves the neck and enters the shaft it becomes a battle-ground for the powerful strains and leverages set up by the lower limb in motion, and hence its own strength must be greatly increased. Although shaft fixation must be used when the neck no longer exists, the middle part of the bone was described by Frazer as "a hollow, bony cylinder," and it appears improbable that a long metallic stem, however well shaped, will

FIG. 20
Analogy of the capstan to illustrate the great leverage forces that may act upon an intramedullary prosthesis.

lie there long without play, even allowing for adaptations of the bone around it in response to Wolff's law. With knee and ankle joints locked, as when bending forward, the forces acting and reacting on the upper part of such a prosthesis are amplified like those at the end of a long screwdriver or the lever of a hand-operated capstan (Fig. 20).

ANCHORED CUP PROSTHESES

Appliances designed to combine the advantages of cup and replacement arthroplasty were described by Valls (1952) and Fitzgerald (1952), both consisting of a metal cup anchored by a central trifin nail.



(*a*) (*b*)

FIG. 21
Anchored cups.

A cup requires less secure fixation than a complete replacement, for the forces which it transmits will automatically tend to hold it on the femoral head. In favour of fixation is the fact that the natural hip is single-jointed, which would seem to account for the early functional success of head replacements compared with cups. Against fixation is the loss of that stimulus towards the production of new articular cartilage provided by movement of the cup upon the underlying head. Although the trifin nail does prevent movement, such control would be more effective and stress-free if it were distributed peripherally instead of centrally, as for instance by such an arrangement as that shown in Figure 21 (*b*).

THE FEMORAL SLEEVE PROSTHESIS

Lenggenhager (1954), aware of the disadvantages of a central stem, designed an artificial head with a sleeve to lie over the neck like the crown of a tooth (Fig. 22). He pointed out that a cylinder will bear greater loads than a solid stem of equal mass and material, as well as achieve wider distribution of stress. Multiple perforations are provided to anchor the appliance by the growth of living tissue through them. Lenggenhager emphasised that the sleeve must fit the prepared cervical stump as tightly as possible and that it must be hammered on as far as the greater trochanter.

FIG. 22
Femoral sleeve prosthesis of Lenggenhager.

Although it is mechanically attractive, there are serious biological objections to this appliance. Lenggenhager objected to the malevolent effects of central stems on intra-osseous vessels, yet Judet *et al.* (1955) showed equally convincing evidence that important arteries entering the cortex are destroyed by reaming the neck—an essential pre-requisite for the sleeve prosthesis.

During a visit to Berne in 1956 I was able to discuss the results of Lenggenhager's operation with a member of his team. The operation was initially a functional success, but in many cases it was complicated after a while by gross spur formation and osteophytosis round the base of the sleeve. A change-over from acrylic to metal made no difference to this, although it did prevent breakage. The Lenggenhager clinic has now abandoned the method in favour of an anchored-cup arthroplasty of the Fitzgerald type.

DISCUSSION

It is fair to say that cup arthroplasty has now established its place in orthopaedic surgery. With proper selection of cases and operative technique it can be depended upon to produce an enduring and satisfactory hip joint in somewhere about two years from the time of operation. This prolonged rehabilitation is a trivial price for a young or middle-aged patient to pay for relief of disablement, but one quite beyond the means of an aged person with—for instance—an ununited fracture. For this large group of patients the rapid return to painless weight bearing possible after replacement arthroplasty is what is needed. The remaining section of this paper is concerned with theoretical steps towards the design of a permanent prosthetic replacement, and it is submitted that success will be directly dependent upon mechanical soundness, which in turn will occur ideally with a prosthesis lying so intimately balanced that the surrounding bone will react naturally and dynamically to it according to Wolff's law. In other words, not only must the bone support the prosthesis but the prosthesis must reinforce the bone. The following six propositions are submitted with these ideals in mind.

1. An inert artificial hip should aim at being a free conductor of natural forces with which it lies in equilibrium.

2. It should aim at being stress-free rather than stress-bearing.

3. The more it can be confined to the femoral head and neck, where weight bearing and rotation are concentrated naturally around a common axis, the more it will achieve these aims.

4. When there is a choice the level of section should be planned to spare the superior group of arteries at the cervico-capital junction.

5. The pressure of weight bearing should be distributed to as large an area of bone as possible along the lines of stress within the femur, and without weakening the cortex by perforation.

6. The design should aim at maintaining the length of the femoral neck, and at the same time allow for the possibility of absorption without interference with its mechanics.

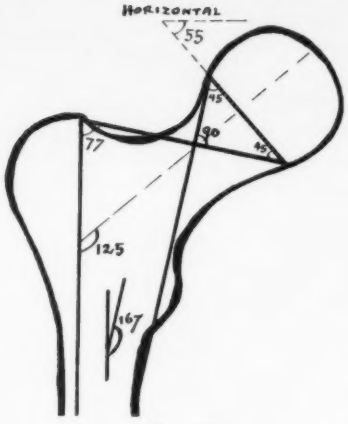


FIG. 23
Weight-bearing forces in the normal femoral neck.

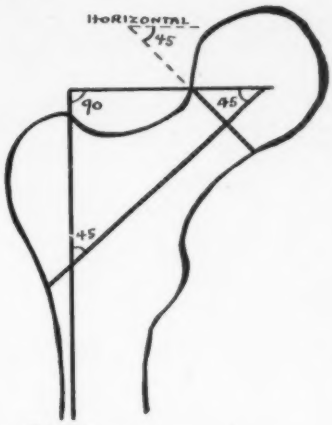


FIG. 24
Weight-bearing forces in the Lippmann prosthesis.

With regard to absorption, it is interesting that Charnley *et al.* (1957) found that in their cases of fracture treated by spring compression the loss of bone was always in the head. This suggests that absorption may be directly related to impairment of blood supply, and makes one feel that a prosthesis must not seek firmer fixation at the expense of blood vessels, for the more it can be kept from exerting pressure on these the better chance it will have of not producing absorption.

In the femoral neck—when the cancellous bone ceases to play its part owing to age—the crane system consists of three cortical components, welded together, but which may be considered separately in terms of a hip prosthesis designed to reinforce them. Thus the top of the shaft—the greater trochanter—is the top of the crane post, the superior cervical cortex the tensional component and the inferior cervical cortex the compression bar or jib. As already seen, the normal arrangements for conducting stress from head to shaft are to some extent reversed owing to the cancellous decussation below the head having ceased to function.

Figure 23 illustrates the angles of weight-bearing forces in the normal hip, taking Inman's (1947) average figures of 125 degrees for neck-shaft angle and 167 degrees for that made by the compression trabeculae with the shaft. This may be compared with the system of forces in the Lippmann prosthesis (Fig. 24), where it will be seen that a new crane, placed farther medially and using smaller leverages, has been substituted for the normal. The diaphysial cylinder is no longer the crane post, but a metal rod down its lumen; the greater trochanter is abandoned and the cortex twice perforated. On these criteria the Moore prosthesis (Fig. 19) comes nearer to imitating the natural system but has the drawbacks of great bulk, and of demanding sacrifice of almost the whole femoral neck.

Figure 25 illustrates a triangle of forces which might be expected to support a prosthesis placed at 30 degrees

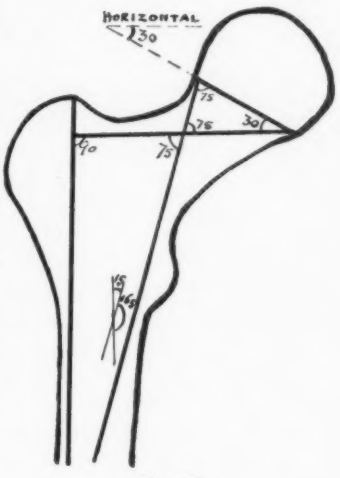


FIG. 25
Triangle of forces to support a prosthesis placed at 30 degrees to the horizontal.

to the horizontal—the angle of stability in fractures and also that at which the epiphysis is placed by nature during the middle years of childhood. This angle lies between that of the original Judet prosthesis (placed at 90 degrees to the neck) and that of its modification (placed at 60 degrees), and might enable some use to be made of tensional as well as compressive forces, working reciprocally within the bone as a replacement for the lost columns.

Though the foregoing seems theoretically the best mechanical arrangement, because of manufacturing difficulties and because of the need to allow more latitude for the descending limb of the prosthesis in relation to neck-angle variations, the experimental models shown in

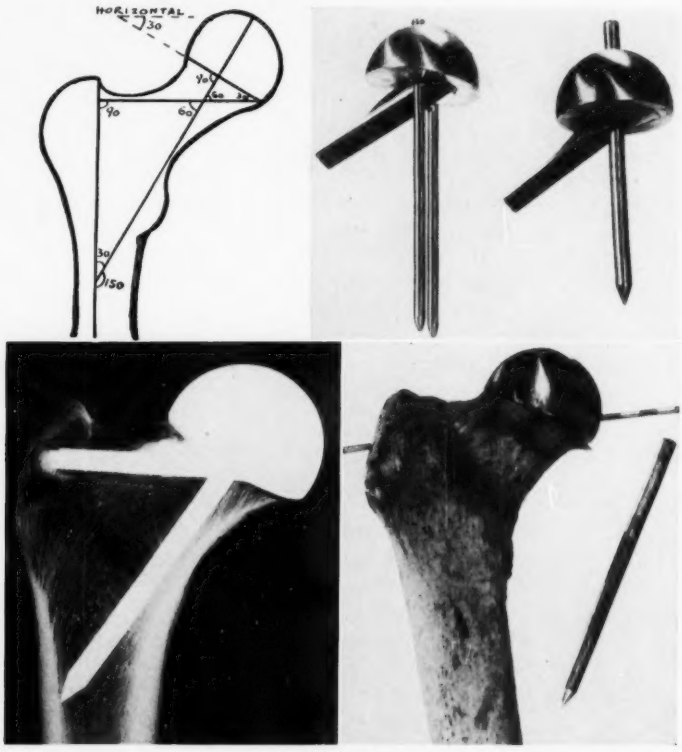


FIG. 26
Experimental models of a hip prosthesis based on the theoretical conceptions described.

Figure 26 have been evolved with the generous aid of Mr Maurice Down. (For full restoration of neck length a more globe-shaped head than this would be necessary, and for elective conservation of the superior arteries a much higher line of section.) The stage of clinical trial has not yet been reached. Recent history emphasises the words of Buxton and Waugh (1954) that " generalisations made from purely mechanical premises may be unreliable when applied to a particular patient," and the theories of this paper are set down as a target for further critical analysis. There are no conclusions.

SUMMARY

1. The structure and blood supply of the femoral head and neck, the mechanics of weight bearing, and the known effects of an inert foreign body are considered in relation to arthroplasty.

2. Some artificial hips are reviewed from the biomechanical standpoint.
3. From the information now available it is inferred that mechanical soundness and clinical success are not only co-related but interdependent; and that the mechanical problem of design offers most scope for further development at the present stage of our knowledge.
4. To this end six propositions are submitted.
5. A theoretical replacement arthroplasty, confined to the head and neck, in which breakdown of the component forces suggests that reciprocal use of both tensional and compressive loads might occur as in the natural femur, is described.

I am very much indebted to Mr Maurice Down, to Mr F. A. Kerry of Saunders Roe Ltd., and to my uncle, Mr J. McFall Smyth, Member of the Institute of Civil Engineers, for their advice on the mechanical forces involved; and to Mr Norman Patterson of Ryde for his painstaking photography. Acknowledgment is also made that this paper in original form was entered successfully in the South-West Metropolitan Regional Board's competition for clinical research (consultants' group 1956) and subsequently read to the Orthopaedic Section of the Royal Society of Medicine.

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STRUCTURAL CHANGES IN BONE ASSOCIATED WITH METALLIC IMPLANTS

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After an investigation into the electrical properties of alloys used in surgery, Clarke and Hickman (1953) suggested that the anodic back E.M.F. (ABE) of a metal was a reproducible electrical property which could be correlated with the behaviour of that metal in living tissue. They emphasised, however, that their results were based on *in vitro* experiments and stated that *in vivo* experiments were in progress to confirm or disprove the validity of their suggestion.

In a preliminary note Hickman (1953) reported that a study of the corrosion and weight loss of metal implants and of the gross structural changes in the surrounding tissue as shown by radiological examination led to the conclusion that the ABE of a metal did in fact give a true measure of its inertness in tissue.

The purpose of this communication is to record the histological changes seen in the long bones of dogs implanted with various metals, and to correlate these changes with the radiological observations and the ABE of the metals in question.

TABLE I

COMPOSITION OF THE ALLOYS USED

Metal	Identification	Major constituents											Potential (*millivolts*)
		Cr	Ni	Mo	Co	Fe	C	Si	Mn	W	Va	Cu	
Tantalum .	—	Super-purity metal											1,650
Cr-Co-Mo alloy	Vitallium	25–30	1 max.	3·7	Balance	·50 max.	1 max.	1 max.	1 max.				650
Cr-Ni-Mo alloy	Alloy " C "	15	57	15		5	Balance			5			880
Cr-Co-Ni alloy.	Alloy " S "	18	14	2	Balance						7·4		750
18/8 SMo steel.	F.M.B.	18	8	2·75			·07	·30	·50				480
18/8 steel. .	F.S.T.	18	8				·10	·60	·80				300
Silver . .	—	Super-purity metal											110
Steel . .	Mild steel	·01	Tr.				·11	·18	·66			Tr.	—480

EXPERIMENTAL METHODS

Selection of metals—It was decided to implant the following eight metals which range from those considered to be completely inert to those that should provoke a very definite tissue reaction. The composition of the alloys is shown in Table I.

Tantalum—Of recent years this metal has been used in surgery because of its inertness. It has the very high ABE of +1,650 mV and was included for this reason.
Vitallium—A chrome-cobalt-molybdenum alloy which has an ABE of +650 mV. This alloy has found an established place in surgery and is stated to be more inert than the stainless steels. This claim appears to have been borne out by extensive clinical use.
Alloy "C"—A chrome-nickel-molybdenum alloy having an ABE of +880 mV.
Alloy "S"—A chrome-cobalt-nickel alloy having an ABE of +750 mV.

In these two alloys the cobalt or molybdenum of Vitallium is replaced by nickel. They were considered worth investigating because they have an ABE higher than that of Vitallium and are less expensive to manufacture.
F.M.B. steel—(18 Cr. 8 Ni. 2·75 Mo—that is, an 18/8 SMo steel).
F.S.T. steel—(18 Cr. 8 Ni.—that is, an 18/8 steel).

The Fracture Committee of the American College of Surgeons recommend 18/8 SMo steel for use in the body. It was decided to include both an 18/8 SMo and an 18/8 steel to determine if there was any appreciable difference in the tissue reactions that they caused and to compare these reactions with those caused by the non-ferrous alloys mentioned above.
Silver—For many years silver was the metal of choice in surgery. Its ABE of +110 mV is very low, which suggests that it should provoke a tissue reaction.
Mild Steel—This steel has an ABE of −480 mV and might therefore be expected to cause gross tissue destruction when compared with other metals selected for this experiment.

The metals, in the form of small rods measuring $\frac{1}{2} \times \frac{5}{32}$ inch, were inserted into the femur and tibia of dogs. All sharp edges having been rounded off, these rods were highly polished, cleaned in xylol, washed in acetone and finally dried between filter paper. Each rod was then weighed, placed in an individual test tube and sterilised in an oven at 160 degrees centigrade for an hour and a half. Previous experiments had shown that sterilisation by this method in no way affected the weight of any of the metals selected.
Surgical procedures—Twenty-four dogs were used, three to assess each metal. In each dog, by means of a hand drill, five holes were made in the lateral aspect of the femur, and four in the medial aspect of the tibia of the opposite leg. The holes, which were five thirty-seconds of an inch in diameter and half an inch apart, passed through the cortex and into the medullary cavity. Five implants were inserted, three into the femur and two into the tibia, leaving two drill holes in each bone as controls. The implants were gently pushed into the holes until the end of the rod was flush with the periosteum.

All dogs made an uneventful recovery after operation, and all skin wounds healed by first intention.

EXPERIMENTAL OBSERVATIONS

Radiological examination—Radiography was carried out immediately after operation, periodically thereafter, and finally at necropsy. The metals under test can be classified into two groups in accordance with the structural changes observed. In the first group, which includes tantalum, alloys "C" and "S," Vitallium, and F.M.B. and F.S.T. steels, the only changes observed were an increased density and thickening of the cortex around the implants (Fig. 1). In the second group, which includes only silver and mild steel, in addition to an increased density and thickening of the cortex there was an area of bone rarefaction (Fig. 2) around the implants.
Necropsy—Immediately after the animals were killed routine necropsy was performed. No clinical abnormalities were detected in any of the abdominal organs; this was confirmed in the case of the liver and kidneys by histological examination. Special attention was directed to the tissue changes in the bone and soft tissues surrounding the implants.

All the implants, except those of silver and mild steel, were firmly embedded in the bone.

Their free surfaces were covered by periosteum and showed no evidence of any local soft-tissue reaction. These implants were as bright as when inserted and showed no sign of corrosion. On the other hand, the implants of silver and mild steel were loose and surrounded by an area of dark discoloured bone. Their free surfaces were covered by a thick layer of fibrous tissue. The silver implants were dulled and those of mild steel grossly corroded. In addition, it was only in these implants of silver and mild steel that a loss in weight could be detected. This was 1·37 and 1·87 milligrams per square centimetre of surface area respectively.

Histological examination—Sections were examined from dogs in each group at three months, six months and one year after operation. In all cases there was a proliferation of the endosteum and a variable degree of fibrosis and new bone formation in the marrow cavities. The metals under test can be classified into two main groups based on the presence or absence of metallic deposits in the tissue spaces and on the structure of the sheaths surrounding the implant tracts.

FIG. 1

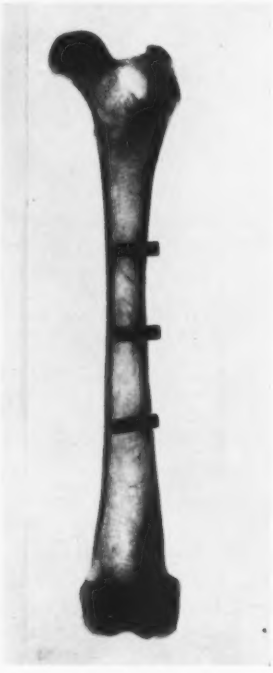

FIG. 2

Figure 1—Increased density and thickening around tantalum implants 367 days after operation. Figure 2—Rarefaction of bone around implants of mild steel 375 days after operation.

In the first group, which includes tantalum, alloys "C" and "S," Vitallium and F.M.B. steel, no metallic deposit was present in the tissue spaces around the implants. The general reaction was mild. Three months and six months after operation the implant tracts were surrounded by a well defined sheath of fibrous tissue with a few areas of necrotic bone. One year after operation the sheaths were of compact bone (Fig. 3) which, in the case of tantalum and F.M.B. steel, contained foci of encapsulated necrotic bone.

In the second group, which includes silver and mild steel, metallic deposits both intra-cellular and extra-cellular were present in the tissue spaces around the implants (Fig. 4), and the general reaction could be classified as severe. The implant tracts three months and six months after operation were surrounded by ill-defined sheaths of fibrous tissue with extensive areas of necrotic bone. One year after operation the implant tracts were surrounded by sheaths of fibrous tissue with foci of encapsulated necrotic bone and areas of new compact bone.

F.S.T. steel appeared to occupy an intermediate position. There were metallic deposits in the tissue spaces which gave a positive reaction to iron as demonstrated by Perl's method, and the general reaction was fairly severe. Three months after operation the tract was surrounded by a sheath of collagen with areas of necrotic bone; but in the dogs examined after six months and after a year there was a thick sheath of fibrous tissue, and the areas of necrotic bone had become encapsulated.

DISCUSSION

It has been postulated (Clarke and Hickman 1953) that the inertness of metals in living tissues can be predicted by measuring their anodic back E.M.F. As this measurement can be carried out with considerable accuracy, it is possible to assign to any metal a definite place in a scale of decreasing inertness. It is not possible to confirm these findings precisely by *in vivo* experiments because no method is available whereby such exact measurements can be obtained. Assessment can be made only by radiological and histological examination of the local changes in the bone and adjacent tissues, and by taking into account the loss in weight of the individual implants as well as the macroscopical evidence of the presence or absence of corrosion. This enables the test metal to be placed in one of two groups. In the first group are those metals which produce a minimum of bone destruction, the implant and any small areas of necrosis becoming encapsulated in compact bone. These metals show no measurable loss of weight nor has any visible corrosion taken place.

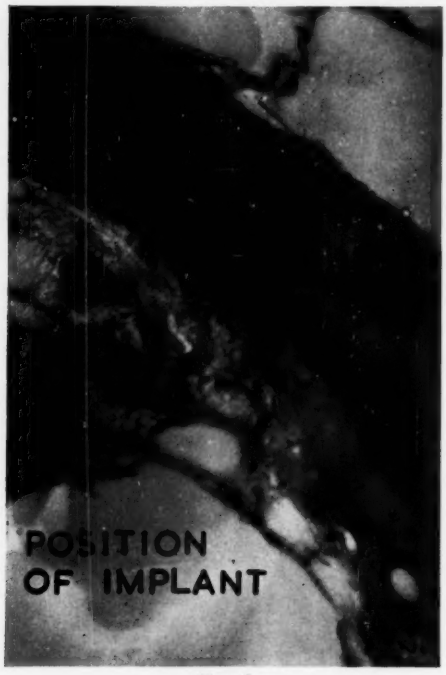

FIG. 3
A well defined sheath of compact new bone around a tantalum implant 367 days after operation.

In the second group there is evidence of gross bone destruction. The implant is encapsulated with fibrous tissue. Free metal is present in the surrounding tissues, and there is loss in weight of the implant and visible corrosion. Thus it seems that metals in the first group, if they have the requisite mechanical properties, are suitable for orthopaedic purposes, whereas those in the second group should undoubtedly be rejected. It is most significant that, of the metals included in this study, all those in the first group have an ABE of over +300 mV while those in the second group are below this figure. It is noteworthy that F.S.T. steel, which has an ABE of +300 mV, showed definite metallic deposits in the surrounding bone and was still encapsulated by fibrous tissue a year after operation. For these reasons it is probably better avoided for surgical purposes.

It thus seems safe to conclude that the way in which a metal will react in living tissue may be deduced with reasonable accuracy from a knowledge of its anodic back E.M.F., the boundary between inert and reactive metals lying in the region of +300 mV.

It must be emphasised, however, that the conclusions reached from our experiments are based on the assumption that only a single homogeneous metal is implanted. Insertion into living tissues of dissimilar metals in contact is almost certain to lead to corrosion (Bowden, Williamson and Laing 1955; Cater and Hicks 1956). Similarly the treatment to which a metal prosthesis may be subjected in the course of its manufacture or implantation may profoundly modify its inertness (Bowden and Williamson 1958). Finally, the inertness of a metal is only one of the several factors that must be considered when assessing its suitability for surgical use (Clarke and Hickman 1958).

SUMMARY

1. Radiological and histological observations of the tissue changes resulting from the implantation of various metals in the long bones of dogs are recorded.

FIG. 4

Tract of mild steel implant in tibia 185 days after operation. New tissue composed of bone and fibrous tissue plus massive deposits of iron pigment.

2. Of the metals employed, tantalum, Vitallium, alloys " C " and " S " and F.M.B. steel were inert; silver and mild steel were reactive; F.S.T. steel occupied an intermediate position.
3. A correlation has been demonstrated between the anodic back E.M.F., the weight loss due to corrosion and the histological changes produced.

The authors wish to thank Mr S. F. J. Hodgman, Director, Animal Health Trust Canine Research Station, for providing laboratory and other facilities, without which this work would not have been possible. Also the co-operation of the following firms is gratefully acknowledged for making available samples of their metals. Johnson, Matthey and Co., tantalum and silver; the London Splint Company, Vitallium; Deloro Stellite Limited, Alloys " C " and " S "; Vickers-Firth Limited, F.M.B. and F.S.T. steels; the United Steel Companies Limited, mild steel.

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BONDING OF FRACTURES BY PLASTIC ADHESIVES

Preliminary Report

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Two years ago I began experimental research into the bonding of fractures by amine-cured ethoxyline resins, which are used in industry as adhesives. The first experiments were carried out on the forelegs of sheep. The results of these were so encouraging that, in 1958, the technique was applied to fractures in humans.

PRINCIPLES AND TECHNIQUE

Amine-cured ethoxyline resins are used in industry for casting purposes and, since they have adhesive properties, they are also used in the bonding of metals and other surfaces. The resin is often " filled " with chalk or other inorganic powders to provide " body." The technique consists in adding a measured amount of hardener, or curing agent, to a known amount of resin, which is paste-like in consistency. The mixture of paste and hardener has a pot life of about two hours. The mixing proportions are five or six parts of hardener to 100 parts of adhesive resin. It has been shown in industry that a material bonded by these substances is stronger at the site of union than elsewhere. A study of these methods suggested that if bonding between bone ends could be achieved there might be a practical application in fracture work.

Tests for toxicity—It is known that certain constituents of the resin mixture may have toxic effects in the human body, and it was essential to show whether or not the resin and the amine became completely bonded in the animal; otherwise some of the toxic constituents might be leached out into the blood stream.

To determine whether or not the compound remained localised at the site of application isotope experiments were carried out in conjunction with Dr J. H. Green, of the department of radiochemistry. In experiments on two sheep radioactive calcium^{45} was linked with the resin used for the bonding of fractures of the foreleg. By determining the radioactivity of samples of blood and urine taken daily for six days after the bonding operation it was possible to assess the quantity of resinous material leached out into the blood stream. The results of these experiments were encouraging, for it was shown that the amount of resinous compound reaching the blood stream was infinitesimal, and we were thus able to conclude that the curing of the resin during the surgical operation was virtually complete.

Bacteriology—The only ingredient that could not be sterilised by autoclaving was the amine curing agent. Bacteriological tests were carried out by Dr R. J. Elvy, of the Kanematsu Institute of Pathology of Sydney Hospital. These suggested that the amine was not only sterile but might also have bacteriostatic properties.

PRELIMINARY EXPERIMENTS IN ANIMALS

Sheep were found to be the most suitable animals. Cross Merino wethers were used, varying in age from six months to two years. A total of twenty-five sheep were used for the bonding experiments. In twenty of these the plastic adhesives were used alone, and in the other five plastic adhesives were used in conjunction with inlays of human or rabbit bone. In six cases the limb was reopened after bonding for removal of fragments for microscopic examination.

TECHNIQUE OF OPERATION

The animals were anaesthetised by pentothal through the jugular vein after an injection of atropine. A bloodless field was ensured by Esmarch's bandages. Both bones of the foreleg (the fused metacarpals) were fractured two inches above the hoof.

Bonding of the fracture—The mixed resin was inserted between the bone ends at the site of fracture. In some cases an excessive quantity of paste was deliberately used and in others the bare minimum. The bones were clamped together for ten minutes before closure of the wound. In all cases the same hardener (amine compound) was used, but various adhesives were tried, the only difference in them being the filler compound.

Post-operative treatment—The affected limb was immobilised in a light plaster, and within four days the animal was allowed to run with the rest of the flock. In most cases the plaster was retained for twelve days.

RESULTS

The results are shown in Table I. Of the twenty fractures for which plastic adhesives were used alone, twelve united satisfactorily in ten to twelve days, though with some bowing

TABLE I

Number of operations	Method	Union	Failures
20	Plastic adhesives	Clinically firm in ten days in twelve cases	8 (3 infected)
5	Human and rabbit bone inlays with adhesives	Firm union after six weeks	—

at the fracture site in three cases. Eight fractures failed to unite: in three of these infection occurred and the plastic material was extruded as a mass. The five fractures for which adhesives were used in conjunction with inlays of human and rabbit bone were all firmly united after six weeks.

Causes of failure—The failures were ascribed to errors of technique. Important factors that must be borne in mind are: 1) that moisture interferes with the bonding properties of the resinous paste; 2) that fat globules between the bonding surface and the paste may prevent adhesion; and 3) that the bond takes a few hours at room temperature to become completely solid. In some experiments efforts were made to ensure firm bonding by applying diathermy to the bone ends, and in other cases the bone ends were swabbed with ether. In three cases an infra-red lamp was used to heat the bonded fracture site to hasten setting. In other experiments the temperature of the resin was raised to 100 degrees Fahrenheit before its application between the bones.

Radiological findings—Serial radiographs taken in the weeks after the fracture showed normal callus formation (Figs. 1 and 2).

Histological studies—Biopsy specimens were taken from the united fractures at three weeks, three months and eighteen months. These showed that new bone formation was not interfered with by the plastic. Union occurred by periosteal and endosteal ossification (Figs. 3 to 5), and in some cases new bone was seen to be growing through the plastic. There was no evidence of abnormal reaction to the presence of the plastic.

LATER EXPERIMENTS IN ANIMALS

In a second series of experiments a slightly modified technique was used for bonding fractures of the femur in sheep. To give additional strength it was decided to use long polyethylene plugs shaped to fit the medullary cavity, and to provide further reinforcement outside the bone by casting on to its surface strands or sheets of fibre-glass impregnated with adhesive resin.

FIG. 1

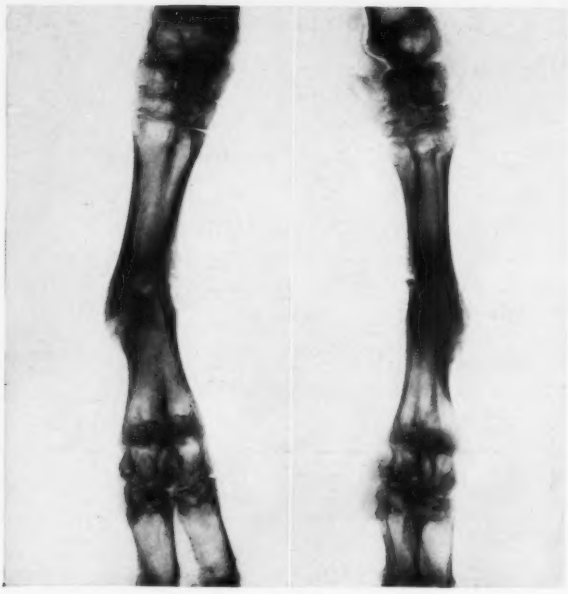


FIG. 2

Figure 1—Radiograph of fused metacarpal of a sheep one week after bonding of a fresh fracture with adhesive resin containing radioactive calcium. The sheep had been freely active on the limb from the day after operation, without external splintage. Figure 2—Radiograph of fused metacarpal of a sheep six weeks after bonding of a fresh fracture. The sheep ran freely from the second day after operation, when the splint was removed. The fracture is united, but with some bowing.

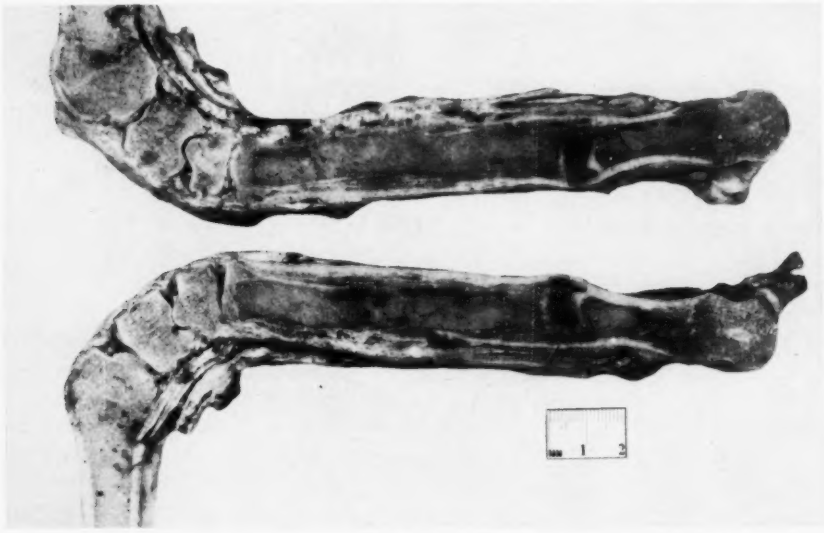


FIG. 3

Divided specimen of fused metacarpal of a sheep ten months after bonding of a fracture with adhesive resin. A large plug of resin was deliberately used. The sheep ran freely with the flock from the second day after operation. The fracture is soundly united. Note that the bone has incorporated the adhesive.

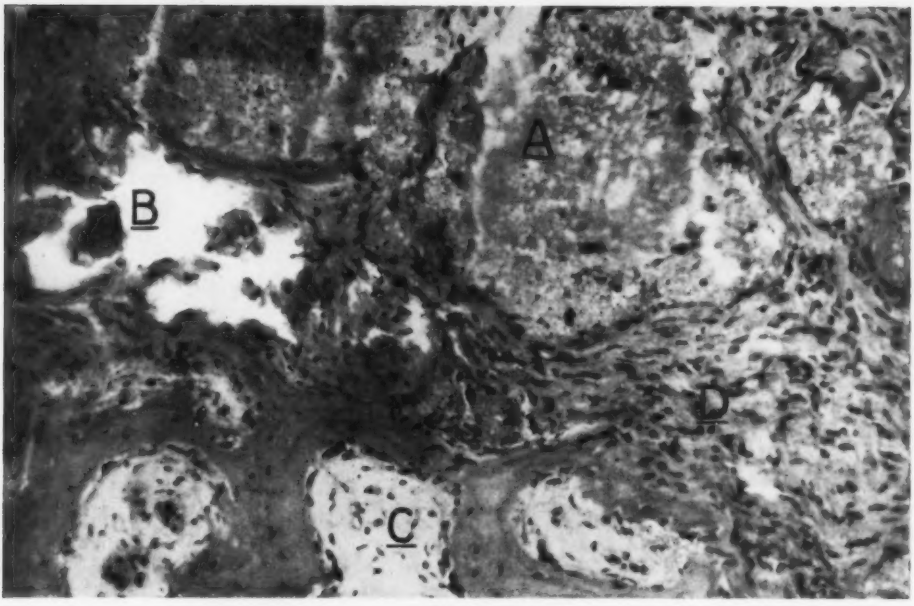


FIG. 4

Section of specimen obtained two months after bonding of a fresh fracture of a sheep's fused metacarpal with adhesive resin. (A) shows the adhesive resin: note its microscopic permeability. (B) shows one of the few giant cells in the area. (C) and (D) show callus and new-formed bone.

FIG. 5

Same animal as in Figure 4. Plastic adhesive (A) interspersed with callus and new-formed bone (B). Note the absence of any marked foreign body reaction.

TECHNIQUE OF OPERATION

The femur was approached from a lateral incision. The bone was sawn through at the mid-shaft.

Bonding of fracture—A long polyethylene plug was inserted in the medullary cavity, bridging the fracture site. The thick resin was applied about the fracture site and heated for two minutes with a controlled inert gas heater, which hastened the curing of the outer layers of the resin. Glass-fibre " rovings " were whipped around the bone for an inch above and below the fracture and were well impregnated with the resin. After the bond had been heated the wound was closed in layers.

Post-operative treatment—Plaster splints were applied for periods varying from six hours to two days.

RESULTS

Four out of six consecutive fractures treated in this manner united successfully, the animals all running freely within two days of the operation.

APPLICATION OF THE METHOD TO FRACTURES IN MAN

Materials—The use of the method in human cases involved the preparation of resins in sterile packages and the standardisation of theatre technique (Figs. 6 to 13). Ethoxyline

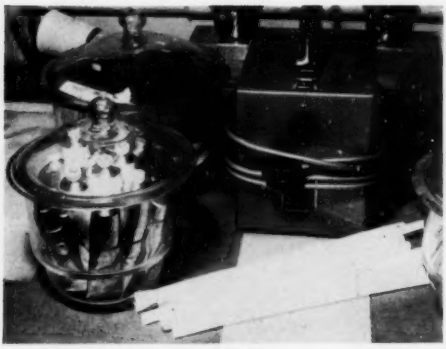


FIG. 6

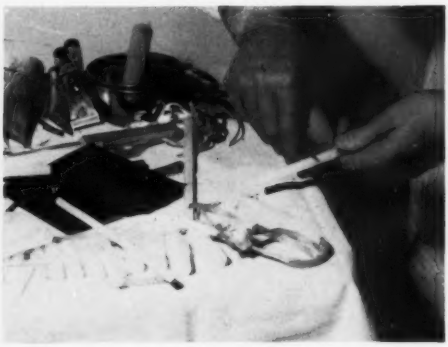


FIG. 7

Theatre technique. Figure 6—Some of the equipment and materials. Mechanical mixers are shown at the back. In front of these is the transformer for the gas heating unit. In the foreground are polyethylene medullary plugs. The jars contain sterile packages of the resin adhesives. Figure 7—A polyethylene plug being shaped to fit the medullary cavity. Note the sterile " rovings " near the surgeon's right hand, and the nylon syringe through which the resin is applied.

FIG. 8

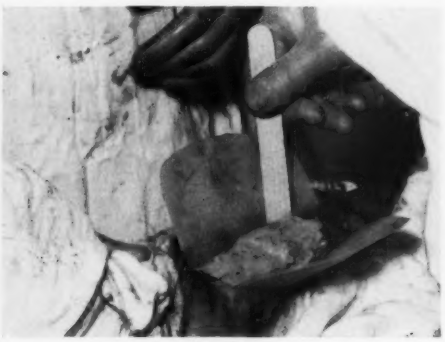


FIG. 9

Theatre technique. Figure 8—Adhesive resin being mixed. Figure 9—Applying the resin with a spatula. The polyethylene sheet is passed behind the bone to protect the soft tissues.

resins were used, with an amine hardener for curing. The mixes were of two kinds, thick and thin. The thick mix, which was applied to the bone surface, was prepared by compounding the basic resin with fillers such as calcium salts, silicates and inert clay. Ground bone may also be used. The thin mix consisted simply of resin and amine curing agent without fillers. It was found to be important to use the correct proportions of resin to hardener. To ensure this, appropriate quantities of resin and of hardener were packed in separate tubes. Also available were: 1) strands of volynised glass-fibre attached by preforming to plastic needles; 2) glass-fibre cloth; 3) polyethylene plugs preformed in sets of various diameter and length to match the medullary cavity of various bones; 4) sets of sterile rovings, autoclaved and dried; and 5) polyethylene sheeting (Fig. 9).

Special theatre equipment—The following items of equipment were provided. 1) Inert gas heater (Fig. 12). This is light and can be wrapped in sterile towels. With this heater a limited stream of heated gas, at controlled temperature, can be directed to the fracture area. 2) A small transformer to which the gas heater is attached (Fig. 6). 3) A cylinder of moisture-free oxygen-free nitrogen. This is attached to the gas heater. 4) A small electrical double mixer. (In the absence of this the resins may be mixed by hand in sterile cardboard containers, using sterile spatulae.) 5) Nylon syringe for application of the resin. (In the absence of this the resin may be applied with a spatula.)

FIG. 10

FIG. 11

Theatre technique. Figure 10—Fibre rovings being impregnated with resin. Figure 11—Passing the rovings round the bone ends. Eight to ten rovings are used.

FIG. 12

FIG. 13

Theatre technique. Figure 12—Heating for three minutes with inert gas heater after completion of the bond with a smooth glass-fibre cloth. Figure 13—Appearance of the bonded fracture before closure of wound.

Technique of bonding (Figs. 9 to 13)—After cleaning of the bone ends the fracture surfaces were approximated. The thick mix was applied about the fracture. Volynised glass-fibre strands impregnated with the thin resin were then roved about the bone junction and the plastic needle was cut free. The final step was to lay on a square of impregnated fibre cloth to provide a smooth finish (Fig. 13). The whole resin join including paste and fibres occupied an inch

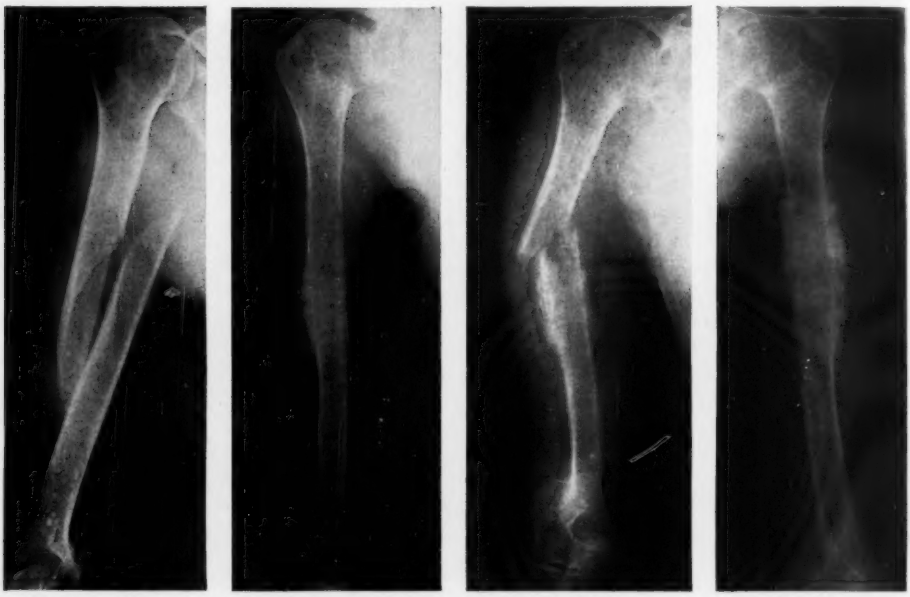


FIG. 14 FIG. 15 FIG. 16 FIG. 17

Case 1. Figure 14—The ununited fracture of the humerus before operation. Figure 15—After first bonding operation (barium sulphate was added to the adhesive to make it radio-opaque). Figure 16—After refracture above original bond. Figure 17—After the second bonding operation. Patient uses the arm freely, without external splintage.

above and below the fracture, and was only a few millimetres in thickness outside the bone. Before closure of the wound the join was heated by the application of inert gas at controlled temperature for a few minutes.

It was found important to use the resins at the correct times; otherwise they may become too brittle in consequence of an exothermic reaction. The ideal time to use both the thick and the thin mix is from ten to thirty minutes after the hardener has been added. It is important that, after mixing of the resins with the hardener, stirring should be continued until the resin is used. After operation the limb must be splinted for at least twelve hours to prevent movement at the site of bonding while the resins are finally curing.

CASE REPORTS

Case 1—Woman aged seventy-seven, referred from a mental hospital. The patient had sustained a long oblique fracture of the shaft of the humerus three months before. Despite treatment by hanging plasters and metal splints the fracture was still mobile (Fig. 14). The patient refused further splintage and was in constant pain.

Operation (August 14, 1958)—A tourniquet was applied and the humerus was exposed. The fragments were found displaced and the fracture was freely mobile. A long polyethylene plug was inserted into the medullary cavity and the fracture was bonded with resins and reinforced with fibre-glass (Fig. 15). After operation the limb was supported on an abduction splint for two days.

Progress—After removal of the splint the patient was able to move the arm without severe pain. The wound healed normally and there was no abnormal general or local reaction. Serial blood films showed no unfavourable response in the red or white cells. Two weeks after the operation the patient was found to have refractured the same humerus (Fig. 16). Because of her mental condition it could not be ascertained whether or not she had fallen or twisted her arm. Radiographs showed that the fracture had occurred at a higher level in the shaft, through previously intact bone.

Further operation—The humerus was again exposed, this time without a tourniquet. The previous plastic join was found to be intact and there was no evidence of excessive local tissue reaction. The plastic join was extended upwards to include the second fracture (Fig. 17). Specimens of the first plastic join were taken for histological examination, and the sections showed healthy callus, without any abnormal reaction. Further progress so far has been satisfactory.

Case 2—Man aged twenty-five, subject to epileptic fits. This patient sustained a compound fracture of the right tibia and fibula in December 1957. The fracture had failed to unite after plating (Fig. 18).

FIG. 18

FIG. 19

Case 2—Ununited fractures of tibia and fibula, before operation. Figure 19—After bonding with adhesive resin.

Operation (August 22, 1958)—After a tourniquet had been applied the fracture was exposed and the plate removed. A pseudarthrosis was demonstrated. The fracture surfaces were freshened and the medullary cavity was opened up. The plastic bond was made subperiosteally

after insertion of a thin polyethylene plug in the narrow medullary cavity (Fig. 19). A plaster was applied for two days.

Progress—The patient's general condition remained satisfactory but there was pyrexia on the third day. The limb remained comfortable and there was no undue swelling, but superficial necrosis occurred in an area of skin three inches long by half an inch wide. Because of this rest with elevation was advised for three weeks. In a clinical test the patient was able to take weight on the limb and walked a few steps without pain four days after the operation. At the time of this report, a month after operation, he is walking freely, taking full weight on the limb.

DISCUSSION

The use of plastic adhesives for the internal bonding of fractures opens up enormous possibilities in fracture treatment. The technique is not complicated, and experimentally the bone so joined has been shown to be very strong; fresh cadaveric specimens of human bone bonded by these adhesives have withstood up to half a ton per square inch on the Vickers testing machine before breaking. None of the resin need be placed between the bony surfaces of the fractured segments: bone is held to bone by an external adhesive collar. However, the animal experiments suggest that it does not matter if some resin is interposed between the bone surfaces. Experimentally, callus formation has not been interfered with, and there has been no unfavourable reaction in specimens studied histologically up to eighteen months from the time of fixation. It is possible that the method may also be applicable to arthrodesis.

It is emphasised that this is no more than a preliminary report, and clearly some years must elapse before the scope of the method can be accurately assessed.

SUMMARY

1. The properties and behaviour of ethoxyline resins, which are already well known in industry, are discussed.

2. Experiments in the use of these compounds for the bonding of fractures of the long bones of sheep are described.

3. There has been no evidence of toxic reaction to the presence of the resin in the tissues.

4. Application of the method to fractures in man has been studied, and two such fractures have been bonded with promising early results.

I am indebted to Mr Warwick Stenning for much helpful advice, to Mr H. Deakin, Honorary Veterinary Surgeon, for his assistance in the animal experiments, to Mr F. McGrath who maintains the Research Unit, to Mr F. Spraggon of Messrs Ciba Ltd. for technical advice, to Dr F. Connors of the Plastic Research Laboratories, Dr A. Palmer of the Pathology Department and Dr J. H. Green of the Department of Radiochemistry, University of Technology, to Dr R. J. Elvy of the Kanematsu Institute of Pathology, Sydney Hospital, and to Mr R. Money of the Medical Photographic Department of the Sydney Hospital.

DENIS JOSEPH GLISSAN

1889–1958

Denis Glissan, who died on May 19, was one of the pioneers of orthopaedic surgery in Australia—one of the first three Australians who trained in orthopaedic surgery and who specialised in this field in Australia after the first world war. Before that there was one orthopaedic practitioner, a German; Gordon Craig and Robert Wade of Sydney did a certain amount of orthopaedic practice as part of the general field of surgery; and Kent Hughes of Melbourne found a curious common interest in otolaryngology and orthopaedics. Not until the first world war did a real interest in orthopaedic surgery arise in Australia, and the first men to devote themselves entirely to it were all disciples of Robert Jones.

Denis Glissan was educated at Riverview and Sydney Grammar School. After graduation in Sydney he served as a Resident Medical Officer at Goulburn Hospital, and then for a short time pursued an assistantship in country practice. In July 1915 he enlisted and served for four years in Gallipoli, Sinai, France and England. He was one of the small group of men selected from the Australian Army Medical Corps for special orthopaedic training in England, and learned his first principles at Alder Hey Military Hospital at Liverpool. He returned to Australia in 1919 and thereafter served on the honorary staff of the Royal Prince Alfred Hospital and of St Vincent's Hospital for over twenty years.

In the second world war he was the first orthopaedic surgeon to be appointed to the 113th Military Hospital at Concord, and he gave to it five years of unremitting work. He was a foundation Fellow of the Royal Australasian College of Surgeons, a founder member and for two years President of the Australian Orthopaedic Association. Perhaps the body that owes him the greatest debt is the Australian Occupational Therapy Association, of which he was a founder and for some years President.

Lennox Teece writes: " At St Vincent's Hospital he was senior honorary surgeon of the orthopaedic department which he built up from nothing to its present pitch of efficiency. He set the standard of work on a firm, rational basis, avoiding the showy and the ephemeral. Many young men and several of the present honorary staff owe him a debt of gratitude for their early training. It is to some considerable extent due to him that the speciality of orthopaedic surgery in Australia today is accorded a high standard of public and professional respect. His tireless energy and enthusiasm established the Australian Occupational Therapy Association on its present firm footing. As a surgeon he was conservative and a perfectionist. He was not to be led astray by some widely acclaimed new procedure or by ill-judged enthusiasm. Everything had to be tried and tested. His meticulous attention to detail was largely responsible for the high standing of his surgical results. Time meant nothing to him. At hospital his operation list would be completed no matter what the hour, and at the end of a long afternoon he would be the freshest person of the whole theatre staff. He had no mercy for laziness, inefficiency or carelessness, and was not slow to speak his mind when he encountered these shortcomings. He devised an effective operation for extensor contraction of the toes and saw it widely adopted throughout the orthopaedic world. He was a man of quiet and unassuming manner; his friends were many and of long standing; yet in addition he enjoyed the respect of his junior colleagues."

John Hoets writes: " My acquaintance with D. J. Glissan began between the first and second world wars with a friendship which became cemented with a real regard for his professional work. His students spoke with affection and reverence of his insistence on correct methods. I personally came under his professional care at that time; I can speak with gratitude and with respect for his discipline and after-care of wounds. I worked with him at 113th Military Hospital at Concord where, in addition to routine visits, every Sunday morning we met together and talked over the problems of our patients. It was a very happy association though pretty hard work and I was impressed more than ever with his meticulous and thoughtful care of patients."

A. F. Dwyer writes: " When Dinny Glissan was forced to retire from practice, orthopaedic surgery in this country lost not only one of its pioneers, but also one of its most original minds. Very few men had as deep an understanding of the form and function of the human foot, and it is a pity that his illness prevented him from writing the monograph he intended. His originality in outlook and technique showed themselves in his highly original solution to the problem of the old, completely avulsed capsulo-tendinous cuff of the shoulder. He was the first to realise the usefulness of the transradiancy and malleability of aluminium for splintage and devised many ingenious ways of using it. He tried to enrol at the Technical College but lacked the necessary union card; but he did become an authority on the use and care of wood-working and metal-working hand tools. A natural teacher, he left his stamp on generations of house surgeons. Irascible in temperament yet patient in demonstration, he impressed on all the importance of methodical clinical work and operative technique, down to the smallest details of nursing. His last years were saddened by confinement to a bed and a wheel chair. Only those who knew his restless temperament realised the frustration he suffered and the genuine fortitude he displayed."

H. Jackson Burrows writes: " Dinny Glissan was a perfectionist, who looked for this quality in his patients and in his assistants. They were left in no doubt when they failed to rise to his own high standards. He held strong principles, and when these were at issue he

was formidable indeed. Yet he had the kindest, gentlest and most generous character—with a sense of humour—that made him the most lovable of men. He both gave and inspired loyalty. His integrity was complete. Everything interested him, particularly natural history in a land richly endowed. He had a rare command of the mother tongue, and his letters were a joy to read because of the grace of their construction and perfection of their vocabulary. He was most happily married to a devoted wife, who shared the tribulations of the illness that clouded his last five years."

CARLO PAIS

1910–1958

On July 21 Professor Carlo Pais died in Genoa at the age of forty-eight years after several months of illness. He had been born in Auronzo (Belluno) in the Italian Alps in 1910, and qualified in Padua in 1934, soon becoming assistant to Professor Delitala in Venice. When Delitala was appointed head of the Institute of Orthopaedics at Naples, Pais was made his First Assistant, and, also as such, he followed Delitala in 1942 when he went to Bologna to take over the place left vacant by the death of Vittorio Putti at the Instituto Rizzoli. In 1948 he was appointed Lecturer in Orthopaedics at Padua, and finally he was elected to the full orthopaedic chair at Genoa in 1954. He was from that year editor of *La Clinica Ortopedica.*

As befitted a typical educated Italian, his manual skill was accompanied by an artistic nature which expressed itself in painting. This was his hidden hobby of which he talked to no one.

The passing of Carlo Pais is a serious blow indeed to Italian orthopaedics, for he represented the type of orthopaedic surgeon now emerging in post-war Italy much closer than before to the methods and system of work prevalent in this country, based more on team work and amiable guidance from the head than on the personal directives of the master. In this connection his appointment to the chair of orthopaedics at Genoa in 1954, after his long training in Venice, Naples and Bologna, was a most timely and welcome decision, as is shown by his election to the Presidency of the Italian Orthopaedic Society for the year 1957–58.

Despite his continuous contributions to the study of orthopaedic conditions in his almost one hundred and twenty varied presentations—some of which, such as those on giant-cell tumours and surgery of the spine, are first class—Pais's disappearance may affect the progress of the speciality in Italy, not so much for the discontinuation of his surgical and clinical work, but by the mere fact that he was not there at the time when important decisions were taken.

He had always been an extremely hard worker despite his relaxed appearance and shy and retiring nature. He owed to this diffidence as much as to his good sense and high ideals, the particular esteem in which he was held by his more senior colleagues, the present leaders of Italian orthopaedics; and many of us had great admiration for his ability to remain on

good and friendly terms with all those strong personalities on whom has fallen the heritage of Codivilla and Putti.

Pais does not leave behind a family of his own as he has died single; but he found homely warmth in his hospital at the side of his assistants and patients who surrounded him by the most touching affection, for there were many who had benefited from his kindness as much as from his professional knowledge and experience.

We in this country join our Italian colleagues in their hour of mourning. J. T.

JOHN KEITH CUNNINGHAME

1911–1957

We have learnt with regret of the death in Wellington, New Zealand, of Mr Keith Cunninghame at the age of forty-six. He was a graduate of the Otago Medical School, a Fellow of the Royal College of Surgeons of England, and a senior orthopaedic surgeon on the visiting staff of the Wellington Hospital. He had been for years the senior full time orthopaedic surgeon on the staff of the Wellington group hospitals. He was largely responsible for the organisation, administration and growth of the orthopaedic department. His professional judgment and skill were allied with a quiet modesty. Outside his professional life he was immersed in a very happy family life. J. K. E.

PROCEEDINGS AND REPORTS OF UNIVERSITIES COLLEGES, COUNCILS AND ASSOCIATIONS

GREAT BRITAIN

VISIT OF THE 1958 TRAVELLING FELLOWS TO THE UNITED STATES OF AMERICA AND CANADA

On March 27, 1958, the five of us gathered at Waterloo Station for the boat train to Southampton. The group consisted of N. J. Blockey (Glasgow), R. A. Bremner (London), M. S. Brett (Salisbury), R. Owen (Liverpool) and M. Lunz (Johannesburg).

On board the *Queen Elizabeth* time dawdled from meal to meal, the unsolved problems of the Old World faded into oblivion and it was difficult to believe that this reputedly exhausting tour had really begun.

Left to right—M. S. Brett, R. Owen, M. Lunz, N. J. Blockey, R. A. Bremner.

On April 1 Manhattan greeted us in sparkling sunshine and we found Dr Halford Hallock ready to smooth our passage through the customs. Our haven for the next seven days was to be the respectable and dignified Columbia Club, set amidst the fury of Manhattan and yet " so like home." With a wave of his magic wand, our fairy Godfather, Dr Mather Cleveland, filled our pockets with a handsome allowance from the heart of Wall Street.

NEW YORK

At the **New York Orthopaedic Hospital,** which occupies one floor of the enormous Columbia-Presbyterian Medical Centre, we attended the Annual Alumni Meeting, presided over by Dr Frank Stinchfield. Apart from a lively show of clinical problems we saw some remarkable experimental work by Dr Andrew Bassett, in which nerve fibres had been enabled to traverse sizable gaps in the sciatic nerve of a cat through a tube of " Millipore," a monomolecular cellulose filter. Warnings were also given of the skeletal complications of steroid therapy and of the acquisition of drug-resistant staphylococci by patients in hospital.

At the **Hospital for Special Surgery** the first item was breakfast with Dr T. C. Thompson and Dr Ramsay Straub. We marvelled at the splendour of this new building, which is the result of metamorphosis following a prolonged larval stage as the historic "Hospital for Ruptured and Crippled." The foundations of a new research building were then being laid and no doubt the steel skeleton is visible as this is written. Dr Philip Wilson gave us the benefit of his experience in the management of giant-cell tumours, and we learned of current investigations into Perthes' disease, bone metabolism and fracture treatment.

In this hospital the sterilisation of operation equipment is by supersonic means.

At **St Luke's Hospital** we learned from Dr David Bosworth and Dr Mather Cleveland about changes in the treatment of bone and joint tuberculosis, rapidly nearing extinction in New York. Dr Fred Thompson gave us a valuable account of the use of his hip prosthesis in the salvage of the ununited femoral neck fracture.

The very few children of New York City suffering from orthopaedic tuberculosis, mostly negroes, are collected at **Seaview Hospital, Staten Island.** Here we were introduced to the drug " Marsalid," the use of which, in spite of its somewhat alarming side effects, is being extended by Dr Bosworth for surgical infections other than tuberculosis. For its general tonic action, perhaps it may be recommended to the next American Travelling Fellows for their use on the 1959 tour.

At the **Hospital for Joint Diseases,** where Dr Milgram and his colleagues gave us a varied programme, we specially remember Dr Emanuel B. Kaplan's diligent search for Truth into the nineteenth century European literature. Now that Dr Kaplan has revealed that the small but famous ligament behind the knee was described by Weitbrecht, and not by Wrisberg, may the ghost of the former lie quiet.

A morning session at **Mount Sinai Hospital** gave us a chance to hear of Dr R. K. Lippmann's experiences with his metal hip transfixion prosthesis, specially designed to prevent femoral neck absorption.

Social activities included a magnificent dinner of welcome given by the Exchange Fellowship Committee, to attend which several senior orthopaedic surgeons had travelled great distances. We were specially honoured by the presence of Dr George Eaton, President of the American Orthopaedic Association, Dr R. I. Harris and Dr Philip Wilson. Here a note was struck which was to be repeated many times throughout the tour: how often we heard the reminiscences of senior men who had visited Britain twenty, thirty or forty years ago, and still felt grateful for the welcome and inspiration which they had received; no exchange fellowship existed for them.

With every evening occupied wining and dining with our hosts, we barely found the time to survey Manhattan by night from the Empire State Building. But not content with this view, we soared aloft with Dr Bosworth in his aircraft *Bonanza* and gained new perspective in surgical travel.

On Easter Sunday rain compelled us to confine our golf to the drawing room carpet. We hope that Dr and Mrs T. Campbell Thompson have since succeeded in replacing the divots.

BOSTON

The air passage from New York to Boston takes little over an hour. There was barely time to dwell on the accumulated impressions of the week in New York before we were " put into orbit " at high velocity by the Boston orthopaedic surgeons at a rousing dinner. And so to bed in the Harvard Club with feelings of the utmost conviviality.

At the **Massachusetts General Hospital** we were disappointed at Dr Joseph S. Barr's absence through sudden illness. Dr Otto E. Aufranc gave us a detailed account of the conditions necessary for success in Vitallium mould arthroplasty, emphasising the need for meticulous attention to operative technique and for patience during the subsequent prolonged period of protected weight bearing. Some patients were also demonstrated following mould arthroplasty of the knee, in whom excellent stability had been obtained.

Intensive research into different aspects of collagen is being carried out at this hospital and in the Department of Biology at the **Massachusetts Institute of Technology.** Here, to our complete dismay, Dr Melvin Glimscher literally conjured with collagen.

In a full programme at the **Children's Medical Centre** Dr William Green and Dr David Grice interested us in their studies of deformity, growth and the circulation of the paralysed leg. The use

of a patten-ended caliper in Perthes' disease was shown to produce a centimetre of shortening of the tibia in one year, which gradually became corrected after removal of the caliper.

We also had a glimpse of Dr Jonathan Cohen's researches into bone structure, and paid a visit to the Poliomyelitis Respiratory Unit at Wellesley.

At the **New England Deaconess Hospital** of the Lahey Clinic Dr George Hammond and his colleagues gave us a morning of papers, among which was a valuable account of the transmetatarsal amputation in peripheral vascular disease by Dr Leland McKittrick.

In contrast to the selective basis of the admissions to the Lahey Clinic it was interesting to visit the **Boston City Hospital,** where Dr Alexander Aitken showed us the organisation of the accident service of this busy municipal hospital. This was one of the few hospitals we visited where the wards held twenty to thirty patients, in common with most of those in Britain.

A very pleasant afternoon was spent with Dr William Rogers and his staff in the offices of the *Journal of Bone and Joint Surgery*, where we saw for ourselves the painstaking work that goes into the production of the Journal.

Our visit to Boston ended with a quick sightseeing tour and on we sped to Montreal the same evening for refuelling by Dr Gordon Petrie and Dr J. Calixte Favreau.

Montreal

On Sunday, April 13, our French-Canadian hosts drove us to Quebec and back along the shores of the St Lawrence River. Dr L. Roy and the Quebec group of orthopaedic surgeons entertained us to lunch and tea in the University Club and conducted us round their historic and beautiful city.

Back in Montreal we visited the **Shriners' Hospital for Crippled Children,** where, among several subjects discussed by Dr Gordon Petrie and his colleagues, we were shown the ambulant treatment of Perthes' disease by wide abduction of the hips.

At the **Montreal General Hospital** a programme of short papers and ward rounds was given by Dr James Shannon and his group.

The pioneer of orthopaedics in Eastern Canada, Dr Edouard Samson, honoured us with a speech of welcome at the **Hopital du Sacré-Coeur.** Dr Guy Lafond demonstrated some cases of tuberculosis of the hip and elbow in adults, with good results from resection of the joints under cover of streptomycin.

As we accompanied Dr Favreau up and down long corridors we goggled in amazement at the evidence of so much wealth lavished on the planning and equipment of the **Hopital Sainte-Justine.** In the luxurious amphitheatre we heard of the experiences of the staff in the management of leg inequality and congenital club foot, of which they had particularly wide experience.

Toronto

At the **Sunnybrook Veterans' Hospital** Dr J. E. Pennal and his colleagues organised a programme which included a demonstration by Dr W. R. Harris of the latest ideas in prosthetic design. We particularly remember the refinements of artificial hand skin, the elegant one-piece plastic prosthesis for the Syme's amputee and the universally acclaimed hip-disarticulation prosthesis.

A meeting with the combined staffs of the **Toronto General Hospital** and the **Hospital for Sick Children** with Dr F. P. Dewar and Dr R. B. Salter in dual chairmanship gave much food for thought. Dr J. E. Hall discussed a simple operation for recession of the gastrocnemius at its insertion, which had given promising results among other operative procedures in over a hundred spastic children. The quantity of clinical material necessary to provide these cases for surgery within two years indicates the huge turnover of patients at this hospital. Some beautiful experimental work in fat embolism and bone regeneration were shown by Dr W. R. Harris and Dr Ian MacNab respectively.

At a large farewell gathering of Toronto surgeons, including Dr W. E. Gallie, Dr R. I. Harris and Dr A. B. Le Mesurier, our thoughts dwelt on the rich heritage created and fostered by these men. With the expected development of Canada in the next generation, Toronto occupies a unique place in orthopaedic teaching and research in the world to-day.

The Niagara Falls were seen at their best in sunshine and later by coloured artificial light as we dined in the Niagara Club with our hosts from Hamilton, Ontario.

Chicago

A fine display of city lights marked out the shoreline as we flew over the inky blackness of Lake Michigan into Chicago Airport, to be met by Dr Edward Compere.

An afternoon was spent at the **Shriners' Hospital for Crippled Children** where Dr Harold Sofield has pioneered the method of intramedullary fixation (" rodding ") of long bones in fragilitas ossium. Apart from the prevention and correction of deformity in these pathetic cases, a functional improvement is often achieved and longitudinal growth is stimulated.

At the **University of Illinois Orthopaedic Hospital** Dr Robert Ray reviewed the fundamental research projects that have been launched in his department within the past year since his arrival. Later Dr C. Lambert showed some patients from the amputee clinic, and a visit was made to the poliomyelitis respiratory centre for a rare display of mechanical gadgets and a demonstration of positive pressure respiration.

It was at the **Children's Memorial Hospital** in 1912 that Dr Fred H. Albee performed the first spinal fusion for scoliosis. A varied selection of cases was shown in which the deformity had been corrected in a localiser cast and fused by the Hibbs technique with no added bone. Twenty children are admitted to this hospital every year with lead poisoning after a meal of painted plaster from the walls of old Chicago homes. Dr Charles Pease and his staff have a unique experience in the extraction of lead from the skeleton with calcium versenate.

The **Orthopaedic Hospital and Research Building of the University of Chicago** form part of the fine campus which is dominated by the Rockefeller Chapel. Dr Dallas Phemister worked here for many years and one of his former assistants is the present chief, Dr Howard Hatcher. Here we were introduced to an attitude of mind born of a vast knowledge of fundamental pathology, clinical wisdom and surgical skill, exemplified by his collection of thirteen local pelvic resections for bone tumours.

Dr John Fahey took us round his patients at **St Francis's Hospital,** near which lies the tomb of the famous Dr J. B. Murphy, and also showed us how a small comprehensive polyclinic can serve the needs of the rapidly growing edge of Chicago.

Milwaukee

Two days were spent in the stimulating company of Dr Walter Blount, Dr A. C. Schmidt and their colleagues. A galaxy of patients attended for our benefit, all illustrating the results of special techniques for which this centre is famous. Here the comprehensive treatment of scoliosis includes the Milwaukee brace, skeletal traction, spinal fusion, spinal osteotomy, fascial transplants and femoral epiphysial stapling, several of which may be employed in the treatment of any one child.

Rochester

The story of the **Mayo Clinic** must remain a myth until one sees the evidence for oneself in Rochester. However, in spite of the size of this organisation, we quickly entered the family spirit which pervades the work and leisure of the orthopaedic group. Apart from the clinical programme given by Dr Herman Young and his colleagues, we witnessed the lightning production of beautiful frozen sections in the laboratory situated next to the operation theatre.

In the Medical Sciences building current research into a bewildering number of problems was reviewed, among which was the stimulation of bone growth by the production of an arteriovenous fistula. Dr J. M. Janes has used this method for the correction of leg length inequality in thirteen children without any alarming complications.

Mention must also be made of an experimental circular ward, in which we saw patients enjoying their privacy and yet remaining within the comforting sight of the nurse, sitting at her desk in the centre. It is interesting to note that a similar experiment in design was made some fifty years ago at the Miller General Hospital in London.

From Rochester to Oklahoma City we flew over hundreds of miles of farmland, and in a brief stop at Kansas City we acquired a little more of the flavour of the Mid-West.

Oklahoma City

In Oklahoma City we rapidly succumbed to the infectious enthusiasm and fresh outlook of this sixty-nine-year-old " boom town." In spite of prohibition there seemed to be no lack of brotherly spirit. We remember the Church of Tomorrow, equipped with escalator and restaurant; the interdenominational Chapel of the New Medical Research Building, contributed by the builders themselves; the Capitol Building set about with oil derricks, and still lacking a dome; and in the background the trumpeting and roar of the Santa Fe express on its way to the West.

Clinical meetings were held at the **Children's Memorial Hospital** and **St Anthony's Hospital** under the chairmanship of Dr D. H. O'Donoghue and Dr Kelly West respectively.

Many surgeons view the surgical reconstruction of torn knee ligaments with gloom, but Dr O'Donoghue has made this subject his own, and demonstrated some giant footballers in various stages of post-operative treatment. He emphasises that treatment must be early, radical and enthusiastically applied to be successful. The constant stream of footballers to Oklahoma City is sufficient testimony to the results. Dr Charles Rountree reviewed his experience of eosinophilic granulomata of bone.

Seeing a nun handling a ciné camera, not to mention being " shot " by one, is an experience we will not forget at St Anthony's. In a later appearance in a television programme various opinions were expressed on the National Health Service, but so far none of us has lost his job.

At the **Bone and Joint Hospital** Dr Earl McBride showed us how to perform his operation for hallux valgus and we saw some excellent results.

Leaving Oklahoma by air we reluctantly turned eastwards, and looked back into the sunset over this teeming city which lay below us, sprawling into the vast landscape.

Memphis

On the way to Memphis we landed at Little Rock, so called by the pioneer explorers who found a firm landing place here when travelling up the Arkansas river, but now world famous for other reasons. Far from being " little," it is the largest city in Arkansas.

Memphis is the capital of the realm of King Cotton, and, though somewhat hindered by the weather, Dr Harold Boyd showed us something of the romantic Mississippi river and the surrounding country.

At the **Campbell Clinic,** where our host was Dr J. S. Speed, we were shown a new specially shaped spring-steel intramedullary rod which Dr Fred Sage is using for fracture of the shaft of the radius. Dr R. A. Calandruccio discussed his current study of the fate of 100 cases of femoral neck fracture in which the viability of the femoral head has been measured with P32.

At the **Crippled Children's Hospital** Dr Alvin Ingram outlined his method of assessing progress in the mental and physical development of the spastic child.

Dr Harold Boyd and Dr Hugh Smith entertained us with a remarkable display of " Son et Lumière," fit for international exhibition.

New Orleans

On a dramatic night flight to New Orleans through successive thunderstorms we surveyed the flooded cotton fields of Mississippi and Louisiana with each lightning flash.

Staying in the French Quarter of the city allowed us to pursue diurnal studies in orthopaedics, history and body culture, for all of which New Orleans is renowned.

After a meeting in the **Ochsner Foundation Hospital,** where we were greeted by Dr Alton Ochsner and Dr Guy Caldwell, we visited the laboratory of Dr Mary Sherman, a migrant from Dr Hatcher's department in Chicago.

At the **Veterans' Hospital** Dr Rufus Alldredge and Dr Daniel Riordan gave us an excellent review of their current ideas and practice in major amputations, which included technical details of Syme's amputation, the suction socket and cineplastic forearm amputations.

These two surgeons have been specially interested in the paralysed extremities in leprosy. At the **National Leprosarium** at Carville we were shown patients who had been subjected to a variety of reconstructive procedures with excellent results. All the patients with leprosy in America are housed free of charge in this institution, if necessary for life, on a voluntary basis. About 200 patients are now resident.

Syme's amputation in the anaesthetic foot and prophylactic transposition of the ulnar nerve for the relief of pain were given special emphasis, among other more intricate procedures.

Duke University, North Carolina

Duke Medical Centre forms part of the University campus, a massive stone tribute to its founder who owned most of American tobacco at one time.

Here we faced a marathon programme covering all aspects of the work in the orthopaedic department, headed by Dr Lennox Baker and Dr Leonard Goldner, together with many other Duke activities, both academic and athletic.

In these days of drug-resistant staphylococci, it is interesting that for the last twenty years surgical operations have been carried out here under ultraviolet radiation, with the virtual elimination of operation infections.

Demonstrations were given in the **Medical Research Building,** the **Cerebral Palsy Hospital** and the **Veterans' Hospital.** We remember a visit to the cigarette factory of Leggett and Myres before rushing on to the pleasant university town of Chapel Hill. Here Dr Beverley Raney and the staff of the orthopaedic department of the **University of North Carolina** gave us a lunch-time programme washed down with " Manhattans " before our departure for Philadelphia.

Philadelphia

After seeing so many new hospitals it was interesting to visit the **Children's Hospital**, now 100 years old, where Dr Jesse Nicholson told us of the ever-increasing problems of the hospital connected with the changing character of the surrounding district.

We were told of the study of juvenile arthritis at this hospital by a combined team of physician, surgeon and physiotherapist. We also heard a series of macabre stories of the vascular complications following the use of " gallows " traction for the fractured femoral shaft in children.

At the **University of Pennsylvania Hospital** we were shown some patients whose hips had been " salvaged " by the trochanteric reconstruction described by Dr Paul C. Colonna.

Another operation for the same purpose was described by Dr J. R. Moore in a meeting at the **Shriners' Hospital.** He has now performed the " cartilaginous cup " arthroplasty in some fifty patients with ununited femoral neck fractures, using the cartilage of the excised femoral head to cover the shaped trochanter.

We also learned, in a Hunterian digression by Dr Moore, that because of the extensive system of air sacs in the bones, a chicken can breathe through the opened medullary cavity in its humerus after ligation of the trachea.

A day was spent at the **Alfred I. du Pont Institute** at Wilmington, where the Medical Director is Dr Alfred Shands, Jun. Here, in the quintessence of luxury, thanks to the du Pont family, an orthopaedic service is provided for the children of Delaware. It serves as a model for similar organisations in other states which are the particular interest of Dr Shands.

Research in this Institution has produced a remarkable film of the ingestion of streptococci by leucocytes.

Washington

The Combined Meeting of Orthopaedic Associations in Washington will be fully reported elsewhere. Whereas for most people this was a period of intense medical and social activity, we enjoyed relative convalescence at the Shoreham Hotel after the previous six weeks' travelling. Here we welcomed the chance of meeting many surgeons and their wives for a second time.

The climax of our tour was reached when we were ushered into the White House through a side door to be addressed by President Eisenhower.

Greenwich, Connecticut

During a visit to Dr Beckett Howorth at **Greenwich Hospital** we absorbed the mature ideas of one man on a wide range of subjects. Dr Howorth has made a special study of slipped upper femoral epiphyses. He has employed an operation for bone pegging of the epiphysial plate in 200 hips without producing avascular necrosis. Better results are obtained by accepting the deformity and promoting bony fusion than by attempting reduction by manipulation or traction.

At Stamford we visited the Rehabilitation Centre provided by local community enterprise for the benefit of persons in need of all types of therapy from " sheltered shop " manual work to speech therapy.

A final day in New York ended in the Rainbow Room of the Rockefeller Building, where we bade farewell to Dr and Mrs Alan de Forest Smith and Dr and Mrs Halford Hallock.

GENERAL REVIEW

It seems worth mentioning some further thoughts on this tour not considered in the narrative account.

History—This tour gave us insight into the orthopaedic history of each centre we visited, often through our meeting the pioneers themselves. Such men as Albee, Hibbs, Phemister and Smith-Petersen still live on in the minds and work of their pupils whom we met.

The complex pattern of hospital organisation suited to the changing needs of each community was difficult to learn on a short visit. However, the parts played by Charity Hospitals, University Hospitals, Veterans' Hospitals and Army and Naval Institutes, Private Clinics and philanthropic institutions such as the Shriners' Hospitals, all became clear.

Training programme—With the expanding population in America, particularly in the West, there is an ever-increasing demand for orthopaedic training. It seems that a man emerges from his residency period fully trained five or six years after graduation, and may enter practice straight away without difficulty, in contrast with the much longer training period demanded in Britain.

Research—We could not fail to be deeply impressed by the dimensions of current research in the United States, nor by the zeal and infectious enthusiasm of those engaged therein.

The stimulus for research is so great that we heard more than once of the relative ease of obtaining capital for building laboratories, but of the difficulty in finding the necessary full-time staff to run them.

Special subjects—With the problems of tuberculosis and poliomyelitis receding, the attention of all is focused on the remaining crippling conditions of childhood. We heard sufficiently diverse opinions

on the management of Perthes' disease, spastic paralysis and congenital deformities to appreciate the intense thought on these subjects. Fairly unanimous opinions were expressed in the management of scoliosis, and the trend towards earlier fusion, in younger children aided by the Risser localisator cast or the Milwaukee brace, was obvious in most centres.

The treatment of the fractured tibia perhaps raised more controversy than any other subject, and, judging from the varieties of treatment and their various complications that were shown to us, the answers are still not known.

The stimulus of keen competition was evident in the field of prosthetics and we were most impressed by the quality and quantity of what we saw, as nearly all centres possessed their own prosthetic workshops.

CONCLUSION

The organisation of this tour must have been a formidable task and we are very grateful to the Secretary, Dr J. Neill Garber, for his work " behind the scenes."

We shall never forget the kindness of all our hosts and their wives who entertained us and welcomed us into their lovely homes.

While this is being written two months later, the new Journal arrives from The Fenway, Boston. As the pages are slowly turned in a reverie, a succession of nostalgic names passes by, and warm memories crowd into the mind to dispel the gloom of a dismally wet English summer's day. The experience of this tour has left a permanent mark on us all. We look forward to welcoming our guests of 1959.

MARTIN S. BRETT.

BRITISH ORTHOPAEDIC ASSOCIATION

Election of Officers and Members of Executive Committee

At a meeting on October 3, 1958, the following were elected:

President for 1960–61: H. J. Seddon (London)

Vice-president for 1959–60: F. W. Holdsworth (Sheffield)

Honorary Secretary for 1959–60: J. Crawford Adams (London)

Members of the Executive Committee for 1959–60:

F. G. Badger (Birmingham)
D. M. Brooks (London)
T. J. Fairbank (Cambridge)
G. E. Thomas (Liverpool)

Editorial Secretary:

E. W. Somerville (Oxford)

Election of Fellows, Members and Associates

The following were elected:

Honorary Fellows:

Robert W. Johnson, Jun. (Baltimore)
A. R. Shands, Jun. (Wilmington)

Corresponding Fellow:

G. F. J. M. Bär (Nijmegen)

Emeritus Fellows:

S. L. Higgs (London)
Sir Walter Mercer (Edinburgh)

Fellows:

C. C. Jeffery (Exeter)
A. S. McConkey (Vancouver)

Members:

H. J. Hambury (Swansea)
M. H. M. Harrison (Birmingham)
N. T. Holden (Enfield)
W. B. Law (Hobart)
J. L. Mangan (Manchester)
W. E. Swaney (Melbourne)
T. E. Stoker (Carshalton)

Associates:

S. K. Bulchandani (Liverpool)
Max Geiser (Berne)
E. J. Kirwan (Nicosia)
J. D. G. McNeil-Smith (Jamaica)
I. J. McQueen (Bristol)
R. A. M. McVicar (Mombasa)
B. K. Madden (Oswestry)
Kingsley W. Mills (London)
J. Piggot (Exeter)
E. R. Price (Sheffield)
H. A. Sissons (London)
T. Smithuis (Breda)
K. H. Stone (London)
R. W. G. Stuart (Bulawayo)
J. A. Turner (Ascot)
William Wilson (Royal Navy)

REGIONAL ORTHOPAEDIC CLUBS

SOUTH-WEST ORTHOPAEDIC CLUB

A meeting of the South-West Orthopaedic Club was held at Musgrove Park Hospital, Taunton, on April 26, 1958. Mr R. F. Winckworth was in the chair, and thirty-five members were present.

Clinical cases shown by *Mr R. F. Winckworth*, *Mr A. E. Jowett* and *Dr M. Hubbard* included the following.

Gout—A woman of thirty-four was shown with gout affecting both hands. The illness commenced in 1946 with swelling of the flexor retinaculum of one hand resembling a compound palmar ganglion. The blood uric acid was raised and the radiographs showed typical appearances of gout in the bones of the hands. There had been a good response to colchicum.

Talipes equino-varus with spina bifida and meningocele—Two children of three and five and a half were shown with this condition. The feet showed severe deformity which was resistant to treatment. After many manipulations, medial release operations, Steindler fasciotomies and elongation of the calcaneal tendons, the feet were now plantigrade. The children had no sign of hydrocephalus and had good intelligence. No operation had been performed for the spinal condition.

Synovioma of knee—A boy of seven was first seen at the age of two years because of pain in the right knee. He attended hospital when aged six because of recurrent swelling of this knee. An arthrotomy was performed and a localised form of villonodular synovitis was found with a well formed nodule. The diseased synovial membrane was removed. So far the swelling had shown no tendency to recur. There had been no definite history of injury.

Slipped upper femoral epiphysis—Three patients were shown, in two of whom both hips were affected. Manipulative reduction had been possible in the case of three hips, and Smith-Petersen nails had been inserted. A cervical osteotomy and Smith-Petersen nail fixation had been performed in one case. The longest period of observation was four years and the functional results so far were satisfactory.

Circumferential skin loss of lower leg treated by split-skin grafting—A woman of seventy-three was shown who had a " degloving " of a large area of the skin of the lower leg. The skin flaps were sutured after cleansing but necrosed. The affected skin was thereupon excised and split-skin grafts were applied, with successful result.

Congenital dislocation of the hip—*Mr A. L. Eyre-Brook* reviewed thirty-five results in cases of congenital dislocation of the hip observed for two and a half to fifteen years after the cessation of treatment. He said that the period of observation in the more recent cases was too short, but indications of future function were fairly evident in the radiographs of such cases. The left hip was affected four times as often as the right (bilateral cases excluded). The sex incidence was: female 33, male 2. The thirty-five cases comprised four groups. 1) Twenty hips treated by traction or frame reduction followed by plaster or other splintage for twelve to eighteen months. 2) Seven hips treated by open reduction or acetabuloplasty followed by plaster for six weeks. 3) Five hips treated by acetabuloplasty with later adduction-rotation osteotomy. 4) Three hips treated by femoral osteotomy (in two cases after excision of the limbus).

The incidence of epiphysitis was rather less in those treated by open operation—17 per cent against 25 per cent. In over half of these cases the condition left no evident deformity, the severer cases all being in the group treated conservatively.

The twenty hips treated by conservative methods alone gave fifteen excellent results. In one the acetabulum remained shallow and in four epiphysial deformity resulted; in one of these the deformity was gross and accompanied some redisplacement, and in two it was associated with epiphysial displacement or partial closure of the epiphysial line causing progressive deformity. In the remaining fifteen cases the radiographs were almost normal. These good results supported Seddon's opinion that the results of conservative treatment " give reason for sober satisfaction." The hips in the group treated conservatively which showed recurrent displacement were treated by acetabuloplasty or osteotomy and were assessed with the other cases treated surgically.

Acetabuloplasty was usually performed for a steeply sloping acetabular roof or large shallow acetabulum in cases of " subluxation," in which the displacement is not great and seems to progress slowly, the labrum never being inverted. In these seven cases the operation was performed between the ages of eighteen months and four years. The clinical and radiographic results varied from excellent to good. Mobilisation was slow in some cases, although immobilisation was never for longer than six weeks.

The five cases to which osteotomy was added to the acetabuloplasty included four in which the operations were performed within a few weeks of each other after failed reduction or recurring

dislocation at four, four and a half, six and a half and seven and a half years. In three of these satisfactory results were obtained.

The three hips treated by osteotomy included two in which Somerville's technique was followed. Some trouble was encountered and Somerville's admirable results were not obtained.

Operative treatment of congenital dislocation of the hip—*Mr G. Blundell Jones* (Exeter) discussed the operative treatment of congenital hip dislocation by the method described by Scott and Somerville of Oxford. After studying Somerville's method at first hand he had dealt with seven hips in five children by this means but had encountered several snags and was unable always to produce similar results. He had reached the following conclusions: 1) rotation osteotomy was not entirely adequate to direct the femoral head centrally but some varus angulation was desirable as well; 2) the level of the osteotomy was important—it should be close to the lesser trochanter; 3) when the plaster was discarded after union of the osteotomy the hip might dislocate when it was very mobile, before the muscles regained their tone: a little post-operative stiffness seemed to help, and some intermediate splintage during mobilisation seemed desirable; 4) in some later cases in which development of the acetabulum had fallen far behind, it might still be necessary to deepen it by a shelf procedure if a really satisfactory hip were to be obtained.

Mr F. C. Durbin (Exeter) showed slides illustrating three cases of congenital dislocation of the hip in which he had employed Somerville's procedure with success. The length of follow-up was three years. Trouble had been encountered in one case because the position of abduction had not been sufficiently maintained in the plaster spica. On removal of the spica after six weeks' immobilisation the affected hip had subluxated. Reduction was effected by holding the legs in plaster in abduction and medial rotation with the hips free. The position was maintained for a further six weeks. He agreed with Mr Blundell Jones that some intermediate splintage in abduction (the Denis Browne hip splint was used) seemed desirable for a short time after the plaster was removed and until muscle control was re-established.

From the subsequent discussion it was clear that many of the speakers believed that conservative treatment should still be followed and tried out first. If any difficulty were encountered in securing reduction removal of the limbus and rotation osteotomy might be performed.

Traumatic dislocation of the hip in children—*Mr J. Piggot* (Exeter) reviewed this injury, which is usually described as rare. Nine cases had been treated at Exeter since 1948. The ages of the patients ranged from four and a half to fifteen years, with an average of ten years. The period of observation was two and a half to ten years (average five years). There has been one instance of avascular necrosis, which became apparent six months after the injury. Two hips showed a widened joint space after reduction of the dislocation: this was attributed to soft-tissue interposition. All patients were free from symptoms at the time of the report.

Avascular necrosis of head of femur after undisplaced transtrochanteric fracture of the femur in children—*Mr F. C. Durbin* reported two cases of this complication occurring in boys aged seven and fourteen. The treatment had consisted in immobilisation in a plaster hip spica for three months. Despite the use of a weight-relieving caliper for eighteen months after the development of avascular necrosis some deformation of the head of the femur had occurred.

Spinal movements—*Mr Hedley Hall* showed a film (from the British Medical Association library) of spinal movements which demonstrated the flexibility of the lower spinal joints in acrobatic dancers. It included ciné-radiographs made by Dr Brailsford.

Flexor-plasty of the elbow—*Mr J. Piggot* said that nineteen flexor-plasties had been performed at Exeter, the first in 1933, and the ages ranged from six to forty-six. Twelve cases were reviewed, the primary condition being poliomyelitis in nine and injury to the brachial plexus in three. Eight results were classed as excellent or good and four as fair or poor. All the patients considered that they had been improved by the operation. The patients in the " fair " and " poor " categories had marked paralysis. They had a better functional than cosmetic result. In none of the twelve patients was a pectoralis major transplant a possible alternative operation. When arthrodesis of the shoulder was required the correct degree of medial rotation and abduction was important.

Tennis elbow—*Mr D. M. Jones* (Bristol) disputed the hitherto accepted hypothesis that tennis elbow was due to a local lesion at the elbow, believing that the symptoms were caused by a neuralgia mainly affecting the distribution of the radial nerve. The cause was the sensitisation of nerve fibres in the cervical spine by changes that were not always capable of radiological demonstration. Further stimuli acting at points along the path of the affected fibres contributed to the picture. Thus the periarticular stabbing pain of tennis elbow might be due to contraction of the lateral epicondylar muscles pulling on the muscular branches of the radial nerve.

Arthrodesis of first metatarso-phalangeal joint—*Mr S. Tupman* (Bath) had used a beef-bone peg as an intramedullary graft to fuse the proximal phalanx to the first metatarsal. He had performed forty-two such arthrodeses in thirty-seven patients. The operation was suitable for five types of case: 1) Hallux valgus with splaying of the forefoot and a short elevated first metatarsal. Keller's operation did not succeed in such a problem. 2) After an unsuccessful Keller's operation, with a painful pseudarthrosis. 3) Hallux rigidus. 4) Rheumatoid arthritis with deformity and lateral deviation of the toes. 5) Poliomyelitis when a flail joint might make it difficult for a patient to put on a shoe. The satisfactory angle of fusion varied from 15 to 30 degrees. After operation a below-knee plaster was retained for ten or twelve weeks. Bony fusion was achieved in thirty-nine cases, with satisfactory walking and a painless foot of good shape. Established non-union occurred in three patients.

SHEFFIELD REGIONAL ORTHOPAEDIC CLUB

The first meeting of the Sheffield Regional Orthopaedic Club was held at Harlow Wood Orthopaedic Hospital on June 21, 1958, under the chairmanship of Mr S. A. S. Malkin.

During the morning patients were available for examination and the problems that they presented were discussed. After lunch short papers were read.

Slipped upper femoral epiphysis—*Mr J. P. Campbell* reviewed the trend towards internal fixation. During 1957 eleven hips (in ten patients) were treated: this compared with five hips in three patients in 1955 and four hips in four patients in 1956. In the 1957 group five patients were obese and five of normal physique. Six patients gave a history of a fairly severe causative injury. Eleven hips were treated by operative fixation, one with a Smith-Petersen nail and ten with Moore's pins; in five of the latter open reduction preceded the fixation. After operation Russell traction was used for six to eight weeks. There was no case of avascular necrosis of the femoral head in this group and all obtained a satisfactory range of hip movement. Open reduction should be attempted only if 1) redisplacement was sufficient to justify correction; 2) the slip was recent as judged by the presence of pain and tenderness in the region of the hip; and 3) radiographs supported the diagnosis of recent slip by the presence of an area of rarefaction in the metaphysis. Otherwise the deformity should be corrected by means of an osteotomy at the level of the lesser trochanter. The correction should be maintained by internal fixation, preferably with a titanium pin and plate.

Osteotomy for osteoarthritis of the knee—*Mr J. P. Jackson* reported the results of fourteen osteotomies carried out to correct a lateral deformity of the knee accompanied by osteoarthritis. Supracondylar osteotomy was performed six times and only one patient subsequently complained of pain. Osteotomy through the upper tibia was followed by some pain in two out of eight cases. Restriction of movement was greater after supracondylar than after tibial osteotomy; consequently the latter was preferred. The danger of vascular complications was discussed, but no such complication had arisen in the series. The operation was considered suitable for patients with disabling osteoarthritis associated with lateral deformity. There was a reasonable chance of relieving pain and retaining a useful range of movement.

The value of local hydrocortisone—*Mr J. D. Malloch* had followed up sixty-six patients treated by injections of hydrocortisone, with physiotherapy where appropriate, until it was fairly certain that the end results of treatment had been obtained. In nineteen cases of tennis elbow the pain was completely relieved in five and unaffected in five, the remainder showing a varying degree of improvement. Of thirteen patients with supraspinatus tendinitis six obtained great benefit and seven very little. In twenty cases of frozen shoulder the relief of pain was complete in four, worth while in five, and negligible in eleven; the improvement in range of movement was complete in two, worthwhile in five and negligible in thirteen. Similar equivocal results were obtained in chronic arthritis and in a few cases of plantar fasciitis and other soft-tissue lesions. There did not seem to be any way of selecting the cases that were likely to do well. No complications had occurred in this series, but suppurative arthritis and allergic reactions had been reported and it seemed doubtful whether continuation of this form of treatment was justified by the results obtained.

Quadricepsplasty—*Mr E. A. Nicoll* had carried out this operation ten times in the last ten years with gratifying results. He recommended the Campbell Thompson procedure, but at times had extended it further by dividing intra-articular adhesions and dissecting the patella from the femur. He stressed the vital importance of after-treatment, which must be persistent and prolonged. Manipulation was always necessary: it should be done early and was often repeated three or four times. Of the ten

operations, seven were for knee stiffness complicating fractures of the femur, many with severe soft-tissue injury or delayed union requiring-grafting and prolonged immobilisation. In two cases there had been comminuted fractures of the tibial plateau, and one operation was for stiffness after synovectomy. In six patients a range of 90 degrees or more was obtained even when there had been less than 10 degrees of flexion before operation.

Paralytic dislocation of hip—*Mr W. Waugh* discussed this problem as it occurred in poliomyelitis. In most cases the onset of the paralysis was before the age of three years and the degree of involvement was variable. Assessment of muscle power around the affected hip was not easy because the normal fulcrum was no longer present. Furthermore in infants co-operation was not possible. In some cases dislocation occurred in the less paralysed hip, suggesting that its cause might lie in a combination of fixed pelvic obliquity and persistent foetal alignment of the proximal part of the femur. The obliquity might have a suprapelvic or an infrapelvic cause or a combination of both. For example, an abduction contracture of one hip could be associated with contracture of the lateral trunk muscles of the opposite side and dislocation of the relatively adducted hip. Primary adduction contracture was not common. Treatment depended upon a careful assessment of possible causes. Somerville's technique of correcting both the abduction contracture and persistent foetal alignment by adduction and rotation osteotomies was demonstrated and discussed.

SOUTH-EAST METROPOLITAN REGIONAL ORTHOPAEDIC CLUB

The Club met at the Princess Alice Hospital, Eastbourne, on June 7, 1958, when cases were presented by *Mr S. A. Jenkins* and *Mr L. A. H. Snowball.*

Osteochondritis dissecans of the hip—In 1944 a boy, then aged eight, had been in hospital for a year for Perthes' disease and had made a full clinical recovery. In 1956 he again developed pain in the hip and radiographs showed a clear area of osteochondritis in the upper part of the femoral head. At exploration an intact cartilage was found, with a discoloured central area. This area was drilled with a bradawl, and four small vertical peg grafts and a Smillie nail were inserted. Traction was applied for two months, and thereafter free mobility without weight bearing was allowed for another month The patient complained only of occasional aching. Radiographs showed a marked diminution in the size of the sclerosed area but full healing had not taken place. *Mr R. C. F. Catterall* suggested that the Smillie nail might have been omitted in view of the difficulty of removing it, but Mr Jenkins replied that he did not intend to do so.

Osteoarthritis of hips with scissor deformity—*Mr L. A. H. Snowball* showed a frail old woman whose deformity had been much improved by osteotomy of one femur, and he sought advice about the treatment of the other hip. Several members suggested that in view of the patient's general condition the least done the better, but the matter of femoral neck " forage " was discussed. *Mr W. H. Gervis* recalled that after extensive forage a gradual increase in the joint space had been claimed. *Mr J. Addison* was sceptical of its value and suggested a prosthetic arthroplasty. Mr Jenkins has since reported that " forage " was carried out soon after the meeting and that the patient was much relieved.

Talipes equino-varus—A patient was shown who had failed to respond to conservative measures and to open soft-tissue correction. *Mr K. Hulbert* favoured continuing conservative measures until the earliest reasonable time for full surgical correction. *Mr R. H. Sewell* and *Mr R. C. F. Catterall* were in favour of further and more radical soft-tissue operations and longer immobilisation, but the general feeling of the meeting was against further immediate surgery.

Arthrodesis of hip—*Mr Jenkins* showed two patients and said he was developing a combination of various known techniques with his own modifications to fulfil certain requirements, as follows: the operation must be easy to perform; it must be reasonably sure of success; it must give a stable, painless hip even in the absence of solid fusion; it must not depend on an accurate fit between opposing surfaces; and it must avoid the use of internal fixation. Through a Smith-Petersen approach the capsule was excised and the articular surfaces were rawed. A large piece of ilium was removed and minced in a bone-mill, and the adjacent surfaces of ilium and femoral neck were rawed. The iliac chips were packed over the raw area and over them were laid all the bone and cartilage chips from femur and acetabulum, including any attached soft tissues. This material was all capable of ossification, and a bulky mass of graft was obtained which, even in the absence of full bony fusion, was sufficient to cause the hip to " seize up," with a functional result as effective as that of a true bony ankylosis. Six patients had been operated upon by this method and the period of plaster fixation had been reduced to eight weeks. The subjective result was good in all cases, but two patients showed a few degrees of movement.

Osteochondritis of medial sesamoid bone of hallux—A girl of eighteen with this condition had been observed for five years. She now had no pain when she wore a metatarsal support, but the sesamoid bone was still tender and the pain returned in the absence of the support. *Mr J. E. Buck* said that he had one case of four years' duration and several others in which removal of the sesamoid bone had not been followed by any complications, and all the patients had remained pain-free. Excision of the sesamoid bone could therefore be recommended.

Removal of fifth toe and metatarsal for excessive splaying—*Mr Jenkins* showed three patients who had been subjected to this operation. The first was a shop assistant of twenty-three who had found it impossible to buy shoes to fit her feet; the second was a girl of twelve who had gradually developed severe splaying after poliomyelitis in infancy; and the third was a games mistress of twenty-four who had also found it impossible to wear ready-made shoes. This last patient was well satisfied, but the first patient was having some trouble with corns on the fourth toes, and the second patient had symptoms from shortening of the tendo calcaneus. *Mr R. H. Sewell* and *Mr P. G. Epps* much preferred to fit the shoes to the feet, and this was the general feeling of the meeting.

UNITED STATES OF AMERICA

A TOUR OF ORTHOPAEDIC CENTRES IN THE UNITED STATES AND CANADA*

From Montreal about two-thirds of the visiting members travelled overnight to Boston for the final stage of the whirlwind tour. We were met at the station by Dr Carlton Rowe. The Saturday academic session was held at the Massachusetts General Hospital, where we were welcomed by Dr Edwin F. Cave and Dr William N. Jones. The meeting was held in the Ether Dome, where ether was first used in 1846. The orthopaedic service of the hospital started in 1900. It was here also that the Smith-Petersen pin was born in 1925.

Dr Otto E. Aufranc reviewed the problems of reconstructive hip surgery by mould arthroplasty. Perseverance in " revision " of the arthroplasties was stressed: of operations for rheumatoid arthritis 30 to 40 per cent required revision, and for osteoarthritis 5 to 10 per cent, but in traumatic cases it was seldom required. He attributed the rarity of post-operative dislocation to: 1) tenotomy only of gluteus medius; 2) transplanting the ilio-psoas anteriorly; and 3) care in maintaining the acetabular dome. This paper provoked a lively discussion.

Dr William H. Harris reassessed eighty-three cases of supposed fibrous dysplasia. Twenty-two had the classical criteria but thirty-one were not cases of true fibrous dysplasia. The onset of symptoms was usually between the ages of four and thirteen years, but one patient first developed symptoms at sixty-eight years.

Dr Robert S. Shaw discussed acute arterial occlusion in the upper extremity: the commonest cause of disappointment was failure to remove distal thrombi. Dr R. Joplin discussed the treatment of foot conditions and described in detail the technique of his " sling " procedure. He showed a patient aged twelve years who had gained a very good result. Dr T. L. DeLorme demonstrated the " halo " method of immobilisation of the cervical spine.

After a full and interesting academic day our Boston hosts entertained us for the evening in small groups. This was an inspired form of hospitality. The quiet of a homely evening was more than welcome. On Sunday our hosts took us to Dr and Mrs Robert Joplin's villa by the sea, and for many reasons we will always remember this clam bake. It was for us very American, apart from the rather British weather and the Anglo-Irish jig that brought the party to a close. Of this final social event of the whirlwind tour, it might well be said: " The best wine was kept to the last, but oh these clams! "

A surprising number survived to attend at the Children's Medical Center on Monday morning. Dr William Green welcomed us. Two patients with recurrent dislocation of the patella were shown. Dr Green did not favour transplantation of the tibial tubercle because of the danger of genu recurvatum. He preferred to release the fascia lata and capsule at different levels on the outer side and to free the vastus medialis and bring it tightly down over the patella on the lateral side of the infrapatellar ligament.

Dr D. S. Grice, professor-elect to the University of Philadelphia, gave us an inventor's description of the twin-graft subtalar arthrodesis. He stressed the importance of getting the calcaneum lined up and inserting the grafts solidly, not just throwing bone into the sinus tarsi. He mentioned the shortcomings of the procedure, especially when there was much deformity distal to the subtalar joint.

* An account of the earlier stages of the tour appeared in the August 1958 number of the Journal (Vol. **40–B**, 595).

He did not recommend the operation for children under four years of age, except in congenital plantar-flexed talus when he used an approach from both sides to free the talus.

Dr Edward Wyman discussed the treatment of slipped upper femoral epiphysis. He favoured fixation with a screw if the slip were moderate. Avascular necrosis of the capital epiphysis occurred in two out of eight patients who were not subjected to osteotomy, and in five out of fifteen in whom osteotomy was performed. He emphasised the need to preserve the retinaculum.

Some of the papers and demonstrations gave added interest by diverging from the strictly orthopaedic field. Dr Joseph Murray, a plastic surgeon, spoke of skin and kidney transplants; Dr Robert E. Gross discussed pump oxygenator problems and showed a very impressive apparatus; and Dr Feller provided a case study of idiopathic hypercalcaemia.

Dr John W. Hayden reviewed fifty cases of simple bone cyst. He stressed the prognostic importance of communication between the cyst and the epiphysial plate. He showed this communication in many cases as a narrow channel. When a communication existed the cysts tended to recur after curettage, grafting and cauterisation with 25 per cent alcohol. This was the " active " phase. All cysts in the " inactive " phase healed.

Dr H. H. Banks surveyed the role of surgery in cerebral palsy. Dr Francis Moore gave a stimulating account of work being done to study the metabolic response to trauma. The effect of treatment with compounds " E " and " F " and endocrines in patients with multiple fractures was discussed. His conclusion was that there was not yet enough knowledge to recommend it for routine treatment. Dr Arthur W. Trott discussed circulatory problems in poliomyelitis, and metallic corrosion as a cause of failure of internal fixation was described by Dr J. Cohen.

Dr Paul P. Griffin and Dr William Bora had studied osteogenic sarcoma in children under sixteen years of age. They recommended irradiation before biopsy (1,200r–1,400r) when the diagnosis was in doubt and further irradiation (7,000r–8,000r) before radical surgery. The behaviour of metastases was studied in nineteen cases: in fourteen the metastases occurred first in the lungs.

This final day was one of the clinical highlights of the tour, and Dr William Green and all the team who helped him merited fully our high opinion of the Children's Medical Center. Boston orthopaedics and hospitality had more than maintained the high standards we had enjoyed everywhere on our tour.

BELGIUM

JOURNÉES ORTHOPÉDIQUES ET CHIRURGICALES DE BRUXELLES

A combined meeting of the Société Belge d'Orthopédie, la Société Belge de Chirurgie, l'Association Belge de Chirurgie and la Société Française d'Orthopédie was held in Brussels from May 8–14, 1958, under the presidency of Dr P. Lorthioir and Dr E. Laduron.

Early Care of Hand Injuries

Introduction—*Dr E. Van der Elst* (Brussels) stated the main classic principles appropriate to hand surgery. To ensure cutaneous covering he preferred free grafts nearly always. In the treatment of infections of the hand he recommended excision followed by suture.

Mallet finger—*Dr J. Lorthioir* (Brussels) described his technique of suture for mallet finger, in which two interlaced wires attached to the two tendinous bands are fixed to the terminal phalanx. He advised an immediate tendon graft to repair flexor tendons severed in " no man's land."

Bony injuries—*Dr H. Evrard* (Montignies-sur-Sambre) described the difficulties of diagnostic radiology of fractures of the scaphoid bone. In Bennett's fracture he recommended bone traction with a stirrup, adduction of the first metacarpal being assured by a band of gauze interposed between that and the traction splint.

Conclusions from a large investigation of results—*Dr G. Calberg* (Brussels) reported a series of clinical studies among 78,000 casualties treated in five years in the Centre de Traumatologie Discca in Brussels. If the subcutaneous surface was not suitable for free grafts, it was necessary to give preference to advancement and rotation flaps or cross-finger flaps, or to use flaps from the arms or the opposite forearm. It was better to avoid abdominal flaps if possible. An accident surgeon must treat 2,500 casualties before meeting a lesion of the flexor tendons; this too explained the mediocre results of most sutures. Late grafting by a specialist in the subject was the solution to the failures. It was useless

to suture the digital nerves beyond the proximal phalanx, the spontaneous recuperation by overlap and invasion being very good. The best treatment of sprains of the fingers was by local injections of hydrocortisone. Infections of the hand were more frequent in winter. It was not necessary to treat them by general antibiotics; local infiltration of high doses of penicillin in solution with procaine would permit early incision of abscesses of the hand and had given excellent results in many thousands of cases. The general quality of results would improve when each hospital possessed in its surgical team a surgeon who had made a complete study of hand surgery.

Rehabilitation—*Dr N. Rouvroy* (Liège) stressed the psychological aspects of treatment of casualties and showed how early and frequent re-education greatly enhanced the expectation of recovery.

Immediate repair of flexor tendons in the digital canal—*Dr C. Verdan* (Lausanne) illustrated in a fascinating way his method of immediate suture of the flexor tendons in " no man's land "—excision of the superficial flexor and resection of three-quarters of the pulley, blocking of the two fragments of the deep flexor tendon by pins transfixing the skin and the tendinous fragments, and suture of the tendon ends by very fine stitches.

Recent fracture of the scaphoid bone—*Dr J. Judet* (Paris) recommended pinning.

Delayed treatment of wounds of the hand—*Dr M. Iselin* (Paris) discussed the advantages of delayed treatment in emergency hand surgery.

Other Papers on Hand Surgery

Surgical treatment of painful neuroma—*Dr D. G. Dieckmann* (Paris) described the treatment of painful nerve bulbs in the fingers by resection and by enclosing the proximal end of the severed nerve in a tube of polythene in the palm of the hand.

Operations for missing thumbs—*Dr Aldo de Negri* (Milan) showed a remarkable film on the pollicisation of the middle finger with resection of the distal two-thirds of the third metacarpal—a fine performance leading to an excellent result. *Mr P. Clarkson* (London) showed good late results of transposition of the big toe to replace a missing thumb.

Reconstruction of the sub-totally amputated hand—*Dr J. W. Littler* (New York) and *Dr R. Tubiana* (Paris) showed cases of the use of metacarpals as phalanges in almost total amputation of the digits.

Grafting for injuries of the flexor tendons—*Dr A. Pallazzi Santos* (Barcelona) showed a film of the treatment of divided flexor tendons by grafts. The animated illustrations were worthy of Mr Walt Disney. *Mr R. G. Pulvertaft* (Derby) gave an account of his experiences in late tendon grafting for injuries of the flexor tendons, and presented technique and prognosis in cases of tendon division in the finger, thumb and palm.

Treatment of nerve injuries in the hand, and tendon transfer in paralysis of the intrinsic muscles—*Dr Jorg Böhler* (Linz) insisted on the necessity of resecting the distal end of a severed nerve back to healthy tissue and showed how the suture must be made with a perfect technique. He illustrated the Bunnell method of tendon transference for ulnar nerve paralysis with the aid of a film of remarkable clarity, each step being first demonstrated on a cadaveric hand.

Plastic treatment of the sequelae of burns or wounds of the hand—*Dr D. Morel Fatio* (Paris) gave a masterly exhibition of the different techniques of skin covering. His practice was to take a full-thickness skin graft from the flexor aspect of the elbow. He rejected thenar flaps and preferred the cross-finger and the cross-forearm and arm flaps. He also preferred flat one-pedicle flaps, and considered that abdominal flaps were of little use in hand surgery.

Periarterial sympathectomy for burns of the hand—*Dr R. Van Doornick* (Brussels) recommended periarterial sympathectomy in certain instances of burnt hands.

Emergency Treatment of Road Injuries

Introduction—*Dr M. Belenger* (Brussels) pointed out the serious increase in road accidents, and advocated the organisation of special ambulance services and the creation of special centres for accident surgery.

General reactions to injury—*Professor J. Gosset* (Paris), after numerous laboratory studies, had arrived at the conclusion of their uselessness. The only way to follow up and treat shock was based on clinical observation. It was necessary to use considerable quantities of blood (at times 23 litres in twenty-four hours), not only in cases of open fracture but also in certain cases of closed fracture, in which the loss of circulating blood could be important. Sodium chloride in solution was the other main treatment for shock, potassium having been discontinued.

Urgency in cranial injuries—*Professor L. Christophe* (Liège) described the different states of coma that occur after a lucid interval in cases of cranial injuries. Endeavouring to establish the moment suitable for operating on a patient in coma, he recommended systematic carotid arteriography for detecting intracranial haematoma.

Urgency in thoracic injuries—*Dr A. Dumont* (Brussels) explained how in certain urgent thoracic cases it might be necessary to remove blood, and how it was necessary in all cases to be careful with the use of blood. He showed equally that, in the case of haemothorax and pneumothorax accompanying serious rib fractures, repeated radiographic examinations were indispensable, because pleural effusion might progressively increase and require aspiration.

Urgency in abdominal injuries—*Professor L. Deloyers* (Brussels) discussed abdominal injuries with special reference to prognosis.

Urgent treatment of injuries of the limbs and spine—*Professor R. Merle d'Aubigné* (Paris) stressed the dangers of manipulation of fractures of the cervical spine and the risk of causing tetraplegia; he recommended skull traction and advised against laminectomy in general. He showed how dislocation of the hip could pass unnoticed, although it must be reduced within twenty-four hours.

Discussion—*Dr M. Arnaud* (Marseilles) stated the incidence of accidents on the road in France and showed that they were more serious on the country roads than in the towns. The increased momentum of the visceral organs with speed explained how readily they could be torn without external injury. *Dr P. Bourret* (Salon en Province), like *Dr F. Wechselberger* (Linz), described the organisation of an emergency service and the ambulance carrying the necessary equipment for the treatment of shocked patients during the journey. The ambulance should carry a doctor, nurses, transfusion and breathing apparatus and the instruments for tracheotomy and for administering oxygen and anaesthetics. *Dr R. Soeur* (Brussels) explained how, in a little country like Belgium with a thick density of population, accidents never happened very far from the large centres. In the towns the victims were nearly always elderly pedestrians.

A banquet, held at the Air Terminus, Sabena, was a truly delightful occasion. Tributes were paid by the several visitors from other countries, including America and Great Britain, to the fine success of the congress and to the charming hospitality of our Belgian hosts and hostesses. The visitors from Great Britain were Harold Bolton, Patrick Clarkson, Guy Pulvertaft and Graham Stack.

HOLLAND

REVIEW OF ORTHOPAEDIC ACTIVITIES

Results of arthroplasty of hip by acrylic prosthesis—At the meeting of the Orthopaedic Association in January 1957 *Dr G. Chapchal* (Utrecht) reviewed the results of Judet arthroplasties of the hip in 180 patients. The best results were obtained when the prosthesis was placed in valgus with the apex of the stem in the medullary canal instead of in the lateral cortex. Bad results were ascribed mainly to absorption of weight-bearing bone in contact with the prosthesis, either in the femoral neck or in the acetabulum. In slightly less than half the cases the prosthesis had more or less changed its position; in 19 per cent this had led to considerable tilting of the prosthesis, with markedly impaired function. When the prosthesis had been inserted in valgus (at an angle of more than 128 degrees with the femoral shaft) its position remained unchanged in two-thirds of the patients, whereas when it had been placed in varus (less than 128 degrees) only 13 per cent remained in the original position. Acrylic heads placed in valgus did not show more tendency to dislocate: dislocation occurred only in cases of a short neck, independent of the direction of the prosthesis. Necrosis of bone in the acetabular roof was often noted after remodelling of the acetabulum. Periarticular calcification was observed in 20 per cent of all cases. Arthroplasty for traumatic lesions of the hip gave the best results, and for rheumatoid arthritis the worst.

Periarticular calcification and ossification after encephalomyelitis—At the June 1957 session of the Netherlands Orthopaedic Association, held in the St Maartens (Orthopaedic) Hospital at Nijmegen, *Dr W. Spiele* reported the history of a ten-years-old boy who had suffered from encephalomyelitis complicating measles in January 1956. He had been in poor condition for many months and developed bed sores and contractures of various joints. Upon his admission to the St Maartens Kliniek he had contractures of both hips, both knees and one elbow. The ankles and the joints of the foot were almost completely ankylosed. Neurological symptoms were absent, and the usual laboratory investigations all gave negative results. Radiographs showed abnormal calcification simulating myositis ossificans about both hips and the right elbow: the left hip was dislocated. The contracture of the left hip was corrected by subtrochanteric osteotomy. Part of the bony mass was removed for microscopic examination: this showed metaplastic bone formation, in continuity with the femoral cortex.

Primary operative fixation of tibial fractures with the Eggers plate: results compared with those of conservative treatment—*Dr K. Boute* reported a series of thirty consecutive fractures of the shaft of the tibia in adults treated with the Eggers plate. He compared the results with those of a comparable series of tibial fractures treated conservatively, either by skeletal traction followed by plaster fixation, or by plaster alone. All types of fracture were represented. The fractures operated upon were clinically solid after an average of 81·7 days. Twenty-two fractures were solid in less than the average time, and seven fractures were solid after an average of 102·2 days. One comminuted fracture in an eighty-one-years-old woman took 137 days to consolidate. With conservative treatment, twenty-nine of thirty fractures had healed after an average of 107 days, twenty-five days more than in the operative series. Twenty-two fractures were clinically healed in less than 107 days, whereas six took an average of 133·6 days. One fracture in a twenty-years-old woman took 242 days, and one comminuted fracture in a thirty-one-years-old woman developed a pseudarthrosis.

The average gain of twenty-five days after operative treatment was not thought a sufficient argument for primary operation, and the conclusion was that conservative treatment should be preferred. Operation was imperative only in the event of failure of closed reduction or recurrent displacement after conservative treatment.

Arthrography of the shoulder—In January 1958 *Dr M. J. Kingma* and *Dr B. den Herder* of Amsterdam reviewed ninety-seven arthrographies of the shoulder. Complete ruptures of the musculo-tendinous cuff were always clearly demonstrated in the contrast picture, and there was a complete agreement between these pictures and the findings at operation. In cases of incomplete rupture of the cuff the results were less reliable. Shoulder arthrography facilitated early diagnosis of rupture of the musculo-tendinous cuff, and should therefore not be postponed. The procedure was not so simple as it might seem: the patient usually suffered a stiff and painful shoulder for one or two days, and extra-articular injection was very painful.

Operative treatment of ruptured musculo-tendinous cuff was advocated by *Dr O. Verbeek*. In incomplete ruptures and in small complete ruptures partial resection of the acromion was done. In large complete ruptures suture was carried out only if tension could be avoided. In the case of large defects a piece of fascia lata was inserted. Partial resection of the acromion was added if necessary. Post-operative treatment in abduction was continued for at least three months, sometimes for as long as four months.

Massive osteolysis—Two cases of massive osteolysis (" osteolyse dit essentielle ") were discussed in March 1958 by *Dr F. A. A. v. d. Weyer*. The first was that of a twelve-years-old girl who entered hospital with a pathological fracture of the right femur. The histological sections obtained at biopsy suggested a cavernous haemangioma. Clinical investigation and laboratory tests gave no further information. All blood values were normal. Radiographs of the entire skeleton showed no further abnormalities. Operation revealed a cavity containing clear fluid. The femoral shaft had disappeared completely. The wall of the cavity was formed by normal muscle. The remainder of the distal part of the femoral shaft, which protruded into the cavity, contained angiomatous tissue. The lesion was still expanding and had now entered the pelvis.

The second case was that of a ten-years-old boy with a lesion which started in the left fibula, and which a year later appeared to invade the tibia. Operative findings were the same as in the case of the girl. The microscopic diagnosis was angioma. After two years the lesion became quiescent and no further progression was found. Twelve years later the boy was still in good health. Although the microscopical picture at the proximal and distal end of the lesion, where normal bone was being invaded, was that of haemangioma, the entire picture was not consistent with that diagnosis. Haemangioma did not lead to such complete disappearance of bone, and did not disappear itself after having destroyed the shaft of a bone.

DENMARK

DANISH ORTHOPAEDIC ASSOCIATION

A meeting of the Danish Orthopaedic Association was held in Copenhagen in March 1957.

The problem of neurosis in treatment of orthopaedic patients—*Dr T. Østergaard* (Helsingor) reviewed twenty-nine patients that he, as psychiatric consultant, had investigated in collaboration with *Dr O. Remvig* at the rehabilitation centre, Hornbaek. Nearly all the patients had been operated upon before admission to the centre. In all cases there was an established somatic lesion as well as a neurosis. In half the cases the neurosis was found to antedate the organic lesion, and in the other half it was secondary. In twenty of the twenty-nine cases the neurosis was the dominant factor and the operation had not been successful. Of the sixteen patients with protruded intervertebral discs twelve were not improved, and operation had aggravated the neurosis in most patients.

Peripheral nerve lesions—*Dr K. Bang Rasmussen* (Copenhagen) had studied 165 nerve lesions: twenty-five of the median nerve, twenty-two of the ulnar, thirteen of the radial and 105 of the nerves in the hand and fingers. In twenty cases only a decompression operation or a neurolysis was done, usually with improvement. Eighteen sutures of the median nerve were done with satisfactory result in thirteen cases. Eleven sutures of the ulnar nerve gave nine good results. Only two of the injured radial nerves were found suitable for suture and in only one was the suture successful.

Dr J. Therkelsen (Copenhagen) had experimented with nerve grafting, using stored nerve transplants in dogs. He found it necessary to resect the zone of fibrosis at the distal suture line by a secondary operation after a grafting procedure, to enable the axons to pass down in the peripheral part of the nerve.

A further meeting of the Association was held in May 1957.

Treatment of bone and joint tuberculosis—*Dr H. Mygind* (Juelsminde) reviewed the treatment of bone and joint tuberculosis at the coastal hospital at Juelsminde in Jutland. In many ways the principles resembled those advocated by Orell in Sweden.

Conservative treatment of delayed union of fractures—*Dr P. Lütken* (Aalborg) reported cases of fractures referred to the orthopaedic clinic from other hospitals with delayed fracture healing, mainly in the tibia and fibula. They were treated by prolonged immobilisation in walking calipers or splints, and most of the fractures eventually united without surgical intervention.

A further meeting of the Association was held in Copenhagen in October 1957.

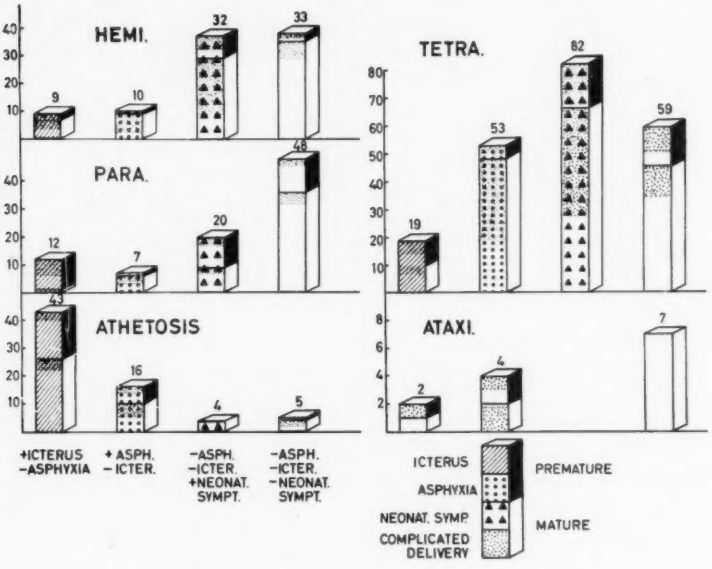
Alkaline phosphatase and calcification—*Dr E. Henrichsen* (Odense) had surprisingly found phosphatase in some of his cultures of fibroblasts by a histochemical method of investigation. He found that its presence was connected with cell degeneration in the cultures. He concluded that the hitherto unknown trigger mechanism to initiate tissue calcification was the production of phosphatase in cells under degeneration. When the cells were totally disintegrated phosphatase had disappeared. The continued calcification in the tissue could be explained by simple crystalline growth.

Post-traumatic reflex dystrophia—*Dr A. Bertelsen* (Copenhagen) gave an account of 148 patients with traumatic dystrophia. Constitutionally a third of the patients were probably neurotic, another third were questionably neurotic and in the remaining third no neurosis could be discovered. Treatment was mainly by sympathetic block, with or without additional cortisone and A.C.T.H. administration. In more severe cases sympathectomy was performed. Dr Bertelsen stressed the importance of recognising early symptoms, because treatment then was nearly always successful. Best results were obtained by sympathectomy.

Determination of local blood circulation by natron 24—*Dr F. Fuglsang* (Copenhagen) gave a preliminary report of his investigation into subcutaneous and muscular clearance of this isotope.

Etiology of cerebral palsy—*Dr S. Brandt* and *Dr V. Westergaard-Nielsen* (Copenhagen) had investigated more than 600 case records of children with cerebral palsy from the cerebral palsy clinic at the Orthopaedic Hospital, Copenhagen. They found that neonatal asphyxia and rhesus incompatibility were responsible for half of extrapyramidal and mixed pyramidal-extrapyramidal cases. Neonatal asphyxia seemed to be of etiological significance in spastic tetraplegia and asymmetrical spastic diplegia, but was of minor importance in symmetrical spastic diplegia, hemiplegia and cerebellar types of cerebral palsy. In spastic diplegia prematurity was found in a large proportion of the cases. There was no evidence that prematurity was an important predisposing cause of neonatal asphyxia. Obstetrical prophylaxis was believed to be very important against neonatal asphyxia.

Etiology, prognosis and results of treatment in cerebral palsy—*Dr P. Plum* (Copenhagen) gave an account of his experience with children with cerebral palsy treated as the department of paediatrics, Rigshospitalet, University of Copenhagen. The illustration shows the natal and neonatal history in 465 cases of cerebral palsy, the numbers in each group being given as the ordinate. Dr Plum's figures supported the views on etiology expressed by Dr S. Brandt (above). As regards intellectual development, he found the prognosis poor when fits, subnormal circumference of the head and strabismus were



Clinical details in 465 cases of cerebral palsy.

present. The prognosis for motor development depended primarily on the degree of the motor handicap. The prognosis for the development of speech depended, in addition to the degree of speech defect, to a great extent upon the intelligence.

The results of treatment were assessed from 203 patients followed up for three to fourteen years. In children with moderately severe motor handicap improvement was much greater when thorough treatment had been given than when treatment had been inadequate. Such difference was not pronounced when the handicap was only slight or when it was very severe.

Surgery in cerebral palsy—*Dr J. Mortens* and *Dr H. Moller* (Copenhagen) presented the results of 325 orthopaedic operations in 114 children with cerebral palsy from the clinic for cerebral palsy at the Orthopaedic Hospital, Copenhagen. Most of the children were spastics; they were operated on during the years 1950 to 1957. The frequency of operation was 16 per cent. Most consisted in myo-tenotomies, tendon lengthenings, stabilising procedures on joints, or bone-correcting operations. Some patients were greatly improved in so far as training had been facilitated and posture and gait improved or made possible. In most of the cases, however, the results had not been so conspicuous, and in many cases only a little had been gained. Because of the severe handicap it was felt that even a slight improvement justified surgery.

SCANDINAVIAN CLUB FOR SURGERY OF THE HAND

The second meeting of the Scandinavian Club for Surgery of the Hand was held in Malmö and Copenhagen on March 22-23, 1958. Thirty-five members were present.

Hand surgery at Allmänna Sjukhuset, Malmö—*Dr Nils Carstam* (Malmö) gave an account of the organisation of the hand surgery unit, of which he is the leader. Fifteen beds are at his disposal. Patients with acute hand injuries are primarily referred to the general surgery unit, and transferred if necessary to the hand unit; or treatment is planned in collaboration with the hand surgeon.

Provision for gliding mechanism of tendons—*Dr Erik Moberg* (Göteborg) gave an account of the different methods in use for providing gliding mechanism for tendons over raw bone surfaces. He now often used a polyethylene membrane placed between the tendon and the bone, especially on the dorsal aspect of the hand and fingers and in the carpal tunnel. He had found the method helpful. The membrane was removed after six months. It was not possible to obtain a standardised type of material, and therefore he had stored a large amount of membrane from a single manufacturer to use over several years.

Surgery of the rheumatic hand—*Dr K. Vainio* (Hainola) related his experience with reconstruction of the severely crippled rheumatic hand. He felt it best to improve function of the elbow and correct deformity of the wrist by arthroplasty or arthrodesis before operating on the hand.

It was often necessary to stabilise a short and hypermobile thumb, and to lengthen the thumb with a bone graft. When the carpo-metacarpal joint was stiff arthroplasty could be helpful. In the fingers two different main deformities could be differentiated in a metacarpo-phalangeal joint. Joints with volar luxation of the finger often retained good mobility and gave little pain; this deformity therefore seldom needed surgery. The other deformity, with stiff flexed metacarpo-phalangeal joints, warranted operation and he recommended resection of the metacarpal heads with shortening of the extensor tendons. The ulnar deviation of the fingers he treated in the manner of Bunnell, by anchoring the extensor apparatus to the radial side of the metacarpo-phalangeal joint. For " intrinsic-plus " deformities he used Littler's method, but when there was hyperextension deformity at the proximal interphalangeal joints or a swan-neck deformity arthrodesis might be necessary.

Open treatment of burned hands—*Dr T. Steenberg* (Malmö) reported the favourable experience of the plastic unit with this form of treatment. Forty-three hands had been treated; in only eight was it necessary to do a secondary excision and grafting procedure.

Pseudarthrosis of the scaphoid bone—*Dr K. Bang Rasmussen* (Copenhagen) opened the discussion, and favourable reports from several members were given on the use of Bentzon's method of treatment, and it was the opinion that in many cases pseudarthrosis of the scaphoid bone was never discovered because it often gave no serious disability. A pseudarthrosis was often discovered only by chance.

Compression of median nerve in carpal tunnel—*Dr N. Carstam* (Malmö) reported two cases in which compression was caused by a ganglion in one case and by thrombosis of an anomalous artery lying close to the nerve in the other.

Manus apostolicus—*Dr L. Mannerfeldt* (Göteborg) gave an interesting and amusing description of his research into the pictorial art concerning the origin of the " manus apostolicus." His investigations were not complete, but so far there was no evidence that a Dupuytren's contracture was responsible.

Hand surgery unit at the Orthopaedic Hospital, Copenhagen—*Dr A. Bertelsen* (Copenhagen) described the development of this unit of which Dr K. Bang Rasmussen is in charge. The hospital's rehabilitation department for hand and arm cases was demonstrated.

Reconstructive surgery in hands paralysed by poliomyelitis—*Dr Nissen Lie* (Oslo) discussed the principles, and *Dr E. Thomasen* (Aarhus) believed that possibly too little had been done in reconstructive hand surgery in patients with severe paralysis of the upper extremity from the great epidemic in Denmark in 1952-53.

Volkmann's contracture—*Dr K. Bang Rasmussen* (Copenhagen) reported seventeen patients, seven of whom had been operated upon after the principles of Seddon, with excision of all necrotic muscles and damaged nerves. *Dr E. Thomasen* (Aarhus) had performed nine such operations, and both had found the procedure helpful. Dr Thomasen, however, had not resected the nerves because he thought that function might recover when the surrounding scar tissue was removed. In the discussion preventive methods—careful observation, and early exploration of vessel and nerve—were stressed.

Sensibility and function of various types of skin transplants on fingers—*Dr L. Mannerfeldt* (Göteborg) gave a preliminary report of the function of and the sensibility in various types of skin grafts to fingers in patients operated upon more than five years ago. The results were discussed by *Dr B. Ponten* (Uppsala).

ANNOUNCEMENTS

BRITISH ORTHOPAEDIC ASSOCIATION MEETINGS IN 1959

The spring meeting will be held in Torquay and Exeter from April 30 to May 2, 1959. The French Society of Orthopaedics and Traumatology and the Belgian Orthopaedic Society have been invited to participate in this meeting. Those wishing to present a communication at the meeting should submit an abstract of about 400 words to the Honorary Secretary, British Orthopaedic Association, 47 Lincoln's Inn Fields, London, W.C.2, **at least three months** before the date of the meeting.

The autumn meeting of the Association will be held in London in early October 1959.

INTERNATIONAL SOCIETY OF ORTHOPAEDIC SURGERY AND TRAUMATOLOGY

The next meeting of the International Society of Orthopaedic Surgery and Traumatology will be held in New York City on September 4–10, 1960. The headquarters hotel will be the Hotel Astor. Suitable and reasonable accommodation will be available at the Astor and in nearby hotels.

The broad subjects for discussion at this meeting will be:

1. Congenital acetabular dysplasia.
2. Osteogenesis and treatment of delayed union and non-union in long bones.
3. Teaching and training in orthopaedic surgery and traumatology and the organisation of hospital services.

There will be an associated audio-visual programme as well as commercial and scientific exhibits.

The meeting is open to all interested members of the medical profession. After the meeting tours to nearby orthopaedic centres will be arranged.

Travel to the United States may be arranged through the American Express Company. Inquiries regarding accommodation should be made to the Hotel Astor, New York City.

UNIVERSITY OF HONG KONG

LECTURESHIP IN ORTHOPAEDIC SURGERY

Applications are invited for the post of Lecturer in Orthopaedic Surgery.

Annual salary (superannuable) is: £1,575 × £50–£2,175 for a man or £1,200 × £40–£1,680 for a woman, together with an expatriation allowance of £225 a year if applicable. The equivalent of income tax in the Colony is comparatively low.

First-class sea passages are provided for expatriate staff and their families on first appointment and leaves.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in Hong Kong and London, is **November 30, 1958.**

Book Reviews

FRACTURES AND OTHER INJURIES. By the Members of the Fracture Clinic of the Massachusetts General Hospital and of the Faculty of the Harvard Medical School. Edited by Edwin F. CAVE, M.D., with thirty-eight other contributors. Drawings by Muriel McLatchie MILLER, photography by Donald WITHEE. $10\frac{1}{2} \times 8$ in. Pp. xvii+863, with 612 figures. Index. 1958. Chicago: The Year Book Publishers, Inc. Agents for the United Kingdom: Interscience Publishers Ltd. Price £10, 10s.

This outstanding volume produced by the staff of the Massachusetts General Hospital in Boston will be welcomed by orthopaedic surgeons throughout the world. In 1938 the staff of the same hospital produced a book on the management of fractures and dislocations. The new volume, with forty-four chapters by thirty-nine contributors, includes all forms of trauma, thus indicating the same trend of practice as in Britain, namely an amplification of established fracture clinics to cover every aspect of trauma in the development of an accident service. The book is luxuriously illustrated and the art of the diagram has been highly developed.

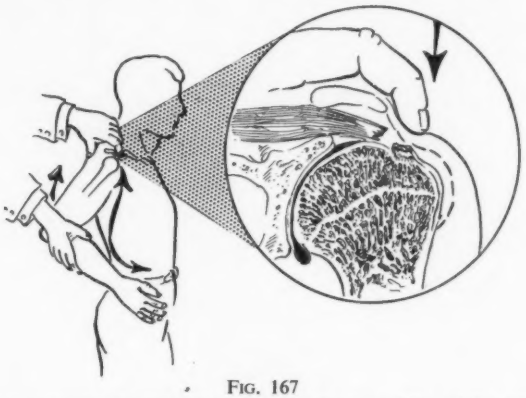


FIG. 167
Demonstrating the method of palpation for tear of the rotator cuff.

One expected, judging from American contributions to the literature, especially the American volume of the *Journal of Bone and Joint Surgery*, to find operative reduction of fractures a prominent feature. In fact, the practice of the staff of the Massachusetts General Hospital conforms with the treatment most widely accepted in Britain—fractures are only treated by operation when there is definite indication. Furthermore, at the beginning of the chapter on operative treatment of fractures, the authors state that " Improper operative interference is one of the most common causes of delayed union or non-union of bone." Perhaps the American pendulum has started to swing away from open operation. The attitude towards rehabilitation can be summarised by quoting the last sentence in the book: " It is urged that the doctor caring for seriously injured patients be aware of all the available rehabilitation procedures and refer the patients to appropriate agencies for necessary occupational and physical therapy." Although exercises are stressed in the treatment of limb injuries, there is no mention of the advisability, or even the possibility, that the surgeon himself should become an active member of the rehabilitation team, a combination which has been proved to be of such value in Britain.

The chapter on healing of fractures is unusually clear, and clinical facts are adequately explained on physiological principles. It is stated at the end of this chapter that " The foundation for delayed union or non-union is laid in the early weeks of treatment and that in most instances complications could be avoided by means at the surgeon's disposal." The reason for non-union in a quarter of fifty-five cases was improper operative interference. The treatment of non-union in the femur was successful with the use of intramedullary nail and subperiosteal iliac bone. There is a clear, concise and readable section on metabolic responses to trauma, tracing the initiation of events in the autonomic

nervous system and subsequent endocrine changes through the hypothalmus to the pituitary or through the adrenal medulla resulting in the secretion of adrenaline or noradrenaline. The section on bone metabolism is a masterpiece. Several complicated-looking diagrams repay close study. This chapter contains the present views in a nutshell. There is a full and clear essay on the early examination and treatment of the injured patient: the treatment of shock is placed on a rational basis, and reasons are given for advice on how to examine an injured patient. There is nothing important left out; there is even a series of diagrams showing how to do a tracheotomy. Intra-arterial transfusion is condemned without reservaton, and it appears that the authors' experience with this procedure has been unhappy. This opinion conflicts with the experience of resuscitation experts in this country, who, using the method of Horton *et al.* (1953), have found it to be a life-saving measure in desperate cases. Shock is dealt with as a short story. It is intensely interesting and considerably more readable than most accounts of this subject.

Injuries of the cervical spine are fully discussed, and several tables of detailed analysis of cases treated at Massachusetts General Hospital adequately sustain the preferred treatment of displaced fractures, namely by traction and then wiring of spinous processes and cancellous bone grafting. An agreeable feature that recurs throughout the book is a short summary of essential points. For instance, at the end of the profusely illustrated discourse on cervical spine injuries, five essential points are emphasised covering transport, advantages of skull traction, indication for operative reduction, the need for fusion and the necessity for specialised training. There is a special chapter on epiphysial injuries with, as elsewhere, profuse illustrations. Major tendon injuries and soft-tissue repairs are given as much consideration as fractures. Injuries to the chest, abdomen and genito-urinary tract are described in full. There are excellent descriptions of injuries to peripheral nerves and blood vessels. The chapter on maxillo-facial injuries is adequate and the line drawings are most helpful. The account on head injuries is beautifully presented, and it is interesting that in the U.S.A. subsequent headaches should be the concern of the neurologist or psychiatrist. Fat embolism is mentioned only briefly. This is the only example of neglect of an important complication of trauma in an otherwise complete text-book.

The authors are to be congratulated on a very fine production indeed.—L. W. PLEWES.

REFERENCE

HORTON, J. A. G., INKSTER, J. S., MACKENZIE, A., and PASK, E. A. (1953): Intra-arterial Transfusion. British Medical Journal, **ii**, 1,294.

FRACTURES AND DISLOCATIONS. By George PERKINS, *M.C.*, M.Ch., F.R.C.S., Consulting Orthopaedic Surgeon at St Thomas's Hospital, London; Consulting Surgeon, Rowley Bristow Orthopaedic Hospital, Pyrford. $9\frac{1}{2} \times 6\frac{1}{2}$ in. Pp. viii + 363, with 255 figures, 1 in colour. Index. 1958. London: University of London, the Athlone Press. Price 57s. 6d.

The author of this beautifully produced book on fractures and dislocations has commanded the respect of the orthopaedic profession as one of its best teachers, as President of the British Orthopaedic Association and as Chairman of the British Editorial Board of the *Journal of Bone and Joint Surgery*. He has a well-earned reputation of not wasting time in coming to the point and this reputation is not diminished by the publication of this book. It is just what is needed to-day. The reader is jolted back from modern orthopaedic gadgetry to basic principles and sound treatment.

Mr Perkins's underlying attitude towards skeletal injuries is well summed up in the words of his preface—" The body is able of itself to take care of most fractures. Occasionally we can improve on nature's methods and sometimes we can hasten the process. Alas, too often our interference delays recovery, and the patient has to struggle to overcome the stiff joints, wasted muscles and impaired control of circulation imposed by our ham-handed methods. A main purpose of this book is to ensure that patients are not harmed by treatment." Unnecessary intervention is firmly rejected and, in this regard particularly, Mr Perkins enhances his reputation as a master of understatement; for example, in discussing the treatment of a fracture of the neck of the fifth metacarpal bone, he writes, " Perfect function and an acceptable cosmetic result follow if the fracture is disregarded and the patient encouraged to use his hand. This shortens the period of disability."

An interesting and somewhat thought-provoking innovation is that every injury is marked by one, two or three stars. One-star injuries can be safely treated by the patient's own doctor. Two-star fractures are within the province of any doctor who has access to a hospital and operation theatre. Three-star fractures should be off-loaded on to the orthopaedic surgeon. The author leaves no

uncertainty in the reader's mind about the importance of certain complications and medico-legal pitfalls.

Although this book has been written primarily for the guidance of general surgeons and general practitioners, there can be few orthopaedic surgeons who will fail to find some pearls of great price in this important publication.—L. W. PLEWES.

BERICHT ÜBER DIE BEI 3,308 UNTERSCHENKELBRÜCHEN IN DEN JAHREN 1926–1950 IM WEINER UNFALLKRANKENHAUS ERZIELTEN BEHANDLUNGSERGEBNISSE. Survey of 3,308 fractures of the leg treated in the Accident Hospital, Vienna, 1926–1950. By Prof. Dr Lorenz BÖHLER, Editor; Reinmar BARTL, Josef ENDER, Heinz JAHNA, Wolfgang KRÖSL, Hans KROTSCHECK, Ernst SCHARIZER and Gottlieb ZRUBECKY. $9\frac{3}{4} \times 6\frac{1}{2}$ in. Pp. iv+257, with 246 figures. 1957. Berlin, Gottingen, Heidelberg: Springer-Verlag. Price DM 39.60.

Here is another monumental statistical survey of injury from the staff of the Vienna Accident Hospital, under the direction of Professor Lorenz Böhler, based on the Hollerith punch card system of case indexing. Much of the statistical evidence has only limited interest to the surgeon, though it cannot be denied that some has medico-legal importance in establishing codes of practice and estimating fracture risks; for instance 20·52 per cent of all conservatively treated fractures of the leg led to some traumatic arthritis of the ankle.

FIGS. 19–21

Different grades of bending fracture. Figure 19—An oblique bending fracture of the leg in the middle third suffered by a twenty-nine-years-old passenger in a motor collision. Figure 20—An oblique bending fracture of the leg with an incompletely separated fragment on the margin of the fracture suffered by a nineteen-years-old locksmith through a step on the outer side of the leg during football. Figure 21—A bending fracture of the lower leg with complete separation of a fragment laterally, suffered by a forty-seven-years-old carpenter through a beam falling on the outer side of the leg. In the middle third of the fibula an 8 centimetre long piece is broken out, the length of which corresponds to the length of the separated tibial fragment.

The 120 statistical tables in 226 pages vary considerably in interest. The figures show that 57·25 per cent of all leg fractures are caused by rotation, and 42·75 per cent by bending. Many people will be surprised by the fact that of the rotational fractures, only 3·86 per cent are due to internal rotation. On the other hand Table 21, giving the day of insertion of a Kirschner wire after the injury, might well have been omitted.

The review is divided into sections, the first dealing with 1,130 closed fractures, the primary treatment being traction and a plaster in 58 per cent. In the second section, treatment of 461 open fractures is discussed. Among the detailed considerations of the cause of failure of union the attitude to the treatment of skin loss must be mentioned: primary excision or grafting is not recommended; secondary suture is preferred, a covering of skin of full thickness being obtained by the use of tension-relieving incisions and subsequent grafting of the gap. It is shown statistically that the extent of primary side-to-side displacement of the tibia exerts a significant and proportional effect on the time of healing. The same influence is seen where side-to-side displacement persists after reduction. It is evident that side-to-side displacement betokens associated soft-tissue injury and that this is probably the primary cause of the delay, but this is not emphasised in the text. The average time that an undisplaced fracture takes to heal is 113 days; with a lateral shift exceeding a quarter the width of the tibia, it rises to 142 days.

The third section deals with the experience of intramedullary nailing of the tibia. It opens and closes with the statement that Böhler has banned the treatment in all cases under his control, and in

twenty-three pages shows the reasons—a generally increased morbidity. The method was used from 1941–44 only, and it had damned itself by the time 110 cases had been dealt with.

In the fourth section the late results of treatment are analysed. It is considered important to accept tibial shortening up to 5 millimetres as normal and, indeed, almost essential for early healing. The loss is explained by the absorption of the bone ends. This statement arises from an examination of the harmful effects of traction that is excessive either in amount or duration.

There is much in this review to stimulate thought, confirm belief and shake convictions. Any statistical evidence related to fractures of the leg will, in future, have to be reviewed in the light cast by the figures in this text. So many aspects of injury to the lower leg are analysed in detail that it is disappointing to find no mention of the influence on healing of double fractures of the tibia.

Included in the volume is a review of traumatic separation of the lower tibial and fibular epiphysis. The absence of brutal figures to the second decimal place lends to this section an additional attraction after what has gone before, and the material and presentation are excellent. Four varieties appear: 1) Pure epiphysial separation 37·5 per cent, 2) Fracture separation of the epiphysis 35·8 per cent, 3) Epiphysial separation with epiphysial fracture 12·3 per cent, 4) Epiphysial separation with fracture of both epiphysis and diaphysis 14·2 per cent. The highest incidence lies between the years of fourteen to sixteen.

This volume cannot be recommended to those allergic to statistics. It cannot be read with comfort even by those insensitive to them, but it is an excellent review of the final results and complications encountered in the routine treatment of fractures of the leg and can be opened with interest at almost any page by anyone wishing to compare his experiences with those of another school.—J. G. BONNIN.

PERIPHERAL NERVE REGENERATION: A Follow-up Study of 3,656 World War II Injuries. Edited by Barnes WOODHALL, M.D., Professor of Neurosurgery, Duke University Medical School, Durham, North Carolina; and Gilbert W. BEEBE, Ph.D., Statistician, Follow-up Agency Division of Medical Sciences National Research Council. 9×5½ in. Pp. xxiv+671, with 22 figures, 60 plates and 286 tables. Index. 1956. Washington, D.C.: United States Government Printing Office. Price $3.75.

War is always a stimulus to the study of injuries of the peripheral nerves. Much of our knowledge of these lesions stems from the careful observations of Weir Mitchell during the American Civil War.

In this monograph a statistical analysis is made of the factors influencing nerve regeneration based on a study of over three and a half thousand nerve injuries three years or more after wounding. In the introduction the casual reader is advised to lay aside the report: your reviewer being full of purpose pressed on, but must admit that long before the end he fell to reading the chapter summaries and cannot therefore claim to be " a brave disciple of our Art." It is regrettable that this immense study is not presented in a more palatable form, because many of the observations are relevant to the nerve injuries of civilian life. It is only when the report escapes from the jargon of the statisticians that we have a report such as the one on Causalgia by White and Selverstone which is a delight to read. Immediately one asks how far a statistical inquiry is justified when there are so many uncontrollable factors influencing recovery, and such wide variation in the estimates of motor and sensory recovery. For example the estimated percentage of good sensory recovery after median nerve suture varied from 10·7 per cent in Chicago to 48 per cent in San Francisco. In general the analysis supports the findings of the more readable British monograph published by the Medical Research Council. In places it is in conflict with informed opinion, as when it is stated that delay in suture, length of gap, state of nerve ends or tension on the suture line do not appear to be associated with significant variation in sensory recovery. Indeed Dr Barnes Woodhall in his analysis of the best and poorest results after peripheral nerve suture states " that adequate motor and sensory return can be obtained . . . when the effector mechanism has not been destroyed by undue delay of suture after injury . . ." Among the more important observations are:—1) Lesions in continuity should not be resected until adequate time has elapsed for the commencement of spontaneous recovery, which is usually superior to the recovery that occurs after resection and suture. 2) Avoid unnecessary delay in the suture of high lesions. Early exploration is always indicated in case the nerve is found to be divided. 3) Lesions of the brachial plexus should in general be treated conservatively, though in *gun-shot wounds* useful recovery may occasionally occur after suture of the upper roots. 4) Causalgia as defined by Weir Mitchell can be successfully treated by sympathectomy.

Stress is rightly laid on the value of reconstructive surgery once the extent of the residual paralysis is known. It is advised that an orthopaedist should be a member of the team, but why not make him responsible for the treatment of the nerve, bone, and soft-tissue injury and its reconstructive surgery, as in Great Britain?—Roland BARNES.

DEGENERATIVE CHANGES IN THE STERNOCLAVICULAR AND ACROMIOCLAVICULAR JOINTS IN VARIOUS DECADES. By Anthony F. DePALMA, M.D., James Edward Professor and Head of the Department of Orthopaedic Surgery, Jefferson Medical College. $9\frac{1}{4} \times 6\frac{1}{2}$ in. Pp. xii+178, with 105 figures. Index. 1957. Springfield, Illinois: Charles C. Thomas, Publisher. Oxford: Blackwell Scientific Publications. Price 42s.

Those who are interested in the diagnostic niceties of common but etiologically obscure shoulder symptoms inevitably find their attention drawn away from the gleno-humeral joint to the smaller joints at either end of the clavicle. It is, therefore, not surprising to find that Anthony DePalma has followed his 1950 publication on "Surgery of the Shoulder" by a study of the acromio-clavicular and sterno-clavicular joints.

The monograph is based on a study of 223 sets of joints obtained at necropsy from individuals ranging in age from premature infants to ninety-four years. This herculean task appears even more formidable when we learn that only subjects were included whose hospital records revealed no clinical abnormality of joint disorder on routine questioning and examining. The gross anatomy and senescent changes in the acromio-clavicular and sterno-clavicular joints are serially described from the first to the ninth decades of life, and there follows a description of the microscopic changes observed during the development and deterioration of the joints. An important chapter is devoted to a meticulous description of the author's classification of the clavicle into three principal types.

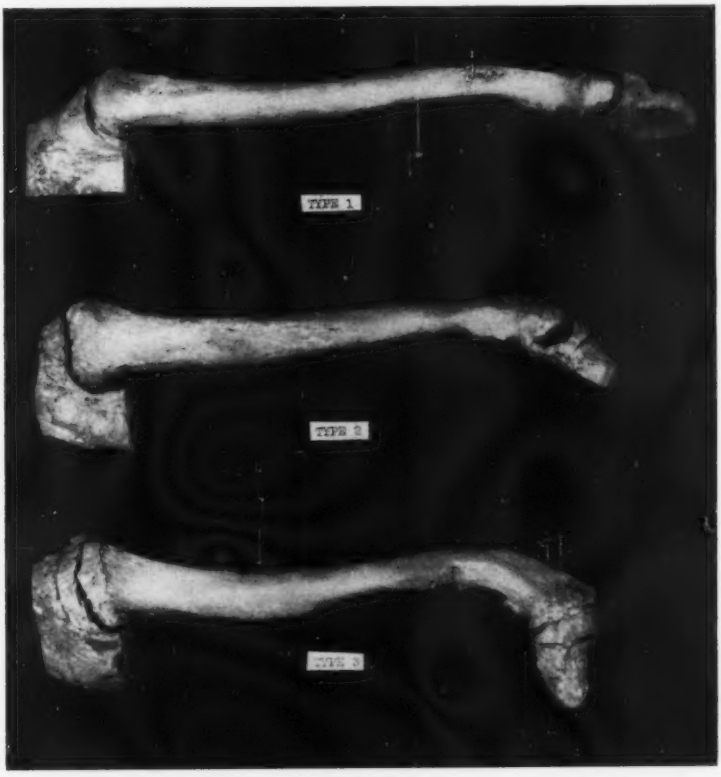


FIG. 100

The author's three types of clavicle: three degrees of anterior torsion of the clavicle with corresponding alteration of the inclination of the joints at each end.

The descriptive part of the book is its most important and is beautifully done. The final twenty-odd pages, however, which contain the interpretation and correlation of the data leave one to doubt the justice of the claim in the Introduction that this study will "... *permit the clinician and surgeon to*

place the correct evaluation on the abnormalities noted in all articulations comprising the shoulder joint in various decades." Similarly, the author does himself an injustice when he says in the Preface that this work "*reveals*" that "*some of the operative procedures designed previously to stabilise these joints when disrupted, should be discarded and others adopted.*" The merit of his contribution to the surgical anatomy and pathology of the shoulder girdle cannot be measured by its possible clinical application. Nor should it be.

DePalma's monograph will no doubt have a permanent place in the libraries as a basic reference for anyone working on the problem of "wear-and-tear" joint degeneration in general, as well as to those who continue to pursue the specific problem of the much-studied but still elusive etiology of chronic pain and dysfunction in the shoulder girdle.—Lipmann KESSEL.

THE FOREQUARTER AMPUTATION. By H. F. MOSELEY, M.A., D.M., M.Ch. (Oxon.), F.R.C.S. (Eng. and Canada), F.A.C.S., Hunterian Professor, Royal College of Surgeons of England; Assistant Professor of Surgery, McGill University; Associate Surgeon, Royal Victoria Hospital, Montreal, Canada. Illustrated by Helen T. MACARTHUR, B.A. 11×9 in. Pp. viii+79, with 11 plates in colour and 25 figures in black and white. 1957. Edinburgh and London: E. & S. Livingstone Ltd. Price 42s.

Two very valuable contributions to our knowledge of the surgery of the root of the upper limb are to be found in the historical account of the forequarter amputation—priority for which is correctly ascribed to Ralph Cuming, Naval Surgeon in Antigua—and in the account of the various traumatic forequarter amputations recorded up to date. It is pleasing to note the author's acknowledgment of help from the learned librarian, W. R. Le Fanu, of the Royal College of Surgeons of England, and from that courteous stalwart, Samuel Wood, of the same institution.

A word of praise is due to the beautiful illustrations which are a feature of the book, but one cannot help wondering whether the operation is worthy of all the pages and illustrations that have been devoted to it, for, as I once wrote of the "hindquarter" amputation, "this is a simple surgical exercise, well suited for an elderly surgeon possessed of a modicum of anatomy and the ability to stand by an operating table for a mere fifty to sixty minutes on end." In the case of the "forequarter" procedure the demands on the surgeon's time are even less.

The book deals with the Berger and the Littlewood procedures: every surgeon is entitled to his preference: from a considerable experience of each I am happier with the anterior approach.

The book is produced in the best style of E. & S. Livingstone.—Gordon GORDON-TAYLOR.

CAMPBELL'S OPERATIVE ORTHOPAEDICS. Editor J. S. SPEED, M.D.; Associate Editor Robert A. KNIGHT, M.D., Memphis, Tenn. Third edition. Volumes I and II. 10×7¼ in. Pp. 37+2,124, with 1,323 figures, including 2 colour plates. 136 pages of index. 1956. London: Henry Kimpton. Price £14, 10s. for two volumes.

This work is so pre-eminent, and so much a boon companion of all of us, that a review of a new edition might seem almost redundant, but it is eight years since we paid tribute to that of 1949.

Then we missed the first chapter of the original edition—on physiology and pathology of bone, joints and the like. Now we have a restored first chapter on basic science, entitled "Surgical Physiology," but having not the least resemblance to its predecessor. The new chapter deals with such general subjects as: the response to injury; the alarm reaction; blood volume; blood pressure and shock; water and electrolytes; acute renal "shutdown"; respiratory and cardiovascular physiology and disturbances; and nutrition. The value of this chapter needs no emphasis. Otherwise the general arrangement of the work remains as in the second edition. The restoration of a chapter on the tissues, as in the first edition, would not be out of keeping.

Trends and advances have called for many changes in most of the chapters, especially in those on skeletal tuberculosis—still rampant in many communities—infantile paralysis and peripheral nerve injuries.

The excellent discussion of the indications for and choice of operation, and of management after operation, commended in our review of the second edition, is, in the third, done better than ever.

H. N. Smith-Petersen is no longer with us, but his place has been worthily filled by Otto E. Aufranc, and there are six other newcomers to the team, nearly all members of the Campbell Clinic and of the University of Tennessee. We are now shocked to learn of the grievous loss of Robert Knight; he has an enduring memorial.—H. Jackson BURROWS.

EXTENSILE EXPOSURE. By Arnold K. HENRY, M.B. (Dub.), M.Ch. (Hon.), Trinity College, Dublin, and Cairo, F.R.C.S.I., Professor of Anatomy, Royal College of Surgeons in Ireland. Second edition. 10+7½ in. Pp. xii+308, with 298 figures. Index. 1957. Edinburgh and London: E. & S. Livingstone Ltd. Price 45s.

This work, the second edition of the much-reprinted first edition of 1945, is really the lineal descendant of the same author's little classic of 1927: *Exposure of Long Bones and Other Surgical Methods*. The excellent approaches there described might not be the best in all circumstances or invariably original: " Henry's approach " to the femur is not bloodless in all hands, and had been described by Thompson in 1918 and doubtless practised before. Nevertheless it was a great book and served a great need. The simplicity of its English, combined with the apt vocabulary of the Celt, gave it a freshness that is indeed rare in medical works.

Its successor, *Extensile Exposure applied to Limb Surgery*, represented a great expansion, as befitted a work now describing the approaches to vessels and nerves as well as to bones. The increased girth brought with it a most unhappy lingo—lacking the pomposity of aldermanic utterance, but having a complexity, or rather perplexity, that quite marred the still wide vocabulary and original approach.

The " second edition," here reviewed, has shed from its title the words " applied to Limb Surgery," but enlargement has continued by geometrical progression, and so it contains even a little more of limb surgery than its immediate parent; for instance, " talectomy from in front " has been added. In the neck, exposures of various important structures are based upon sternomastoid eversion. Exposure of the second costal arch is used, behind, for access to the first part of the left subclavian artery, and, in front, for dealing with pulmonary emboli of the upper thoracic sympathetic and spinal ganglia. An extended retropubic approach is described for access to visceral vessels and for denervation of the hip.

This book remains largely a study in surgical anatomy. Many of the exposures are well-tried in surgery; others await full surgical assessment. It is beautifully got up, but many of the half-tone blocks add nothing useful or graceful to the less costly line drawings of the 1927 volume, from which they are clearly copied.—H. Jackson BURROWS.

REFERENCE

THOMPSON, James E. (1918): Anatomical Methods of Approach in Operations on the Long Bones of the Extremities. Annals of Surgery, **68**, 309.

LUMBAR DISC LESIONS. Pathogenesis and Treatment of Low Back Pain and Sciatica. By J. R. ARMSTRONG, M.D., M.Ch., F.R.C.S., Orthopaedic Surgeon to the Metropolitan Hospital, Lambeth Hospital, Manor House Hospital and Royal Waterloo Hospital for Children and Women. Foreword by H. OSMOND-CLARKE, *C.B.E.*, F.R.C.S. Second edition. 10×7¼ in. Pp. xii+244, with 60 figures, many in colour. 1958. Edinburgh and London: E. & S. Livingstone Ltd. Price 45s.

This comprehensive monograph has received wide recognition and well merited acclaim since it was first published in 1952. Despite the author's assertion in the preface that a second edition has been justified by additions to our knowledge of intervertebral disc lesions, the book has been changed very little. There are four new illustrations, and the remainder of the sixteen-page increase in length is accounted for by new or expanded material relating to the nerve supply of the intervertebral discs, the effects of mental stress on disc structure, nucleography, spondylolisthesis and the technique of arthrodesis of a damaged intervertebral joint. The author has drawn his conclusions from a vast experience of the problems presented by back pain and sciatica, and his views command respect.

The contents seem to fall naturally into three main parts: disc mechanics and pathology, diagnosis and treatment. The first of these, occupying sixty-six pages, follows orthodox teaching and is well illustrated by numerous diagrams. Diagnosis is covered fully in six chapters occupying ninety-eight pages. The emphasis is on clinical methods, and ancillary aids to diagnosis are kept in their proper perspective. Myelography is advised only when the presence of a spinal tumour is suspected, and nucleography is roundly condemned as uncertain and hazardous. The six chapters concerned with treatment occupy sixty-six pages. The author believes that assessments of conservative treatment have often been over-optimistic: only about 20 per cent of all patients are completely cured thereby, 60 or 70 per cent are relieved sufficiently to avoid operation but are left with a reduced tolerance for activity, and 10 or 20 per cent need operation. As to the technique of removing a damaged nucleus,

the author argues in favour of a wide exposure at two levels by hemilaminectomy, but he emphasises the importance of preserving the articular processes. He is opposed to routine primary arthrodesis of the intervertebral joint after excision of a disc nucleus. When arthrodesis is required for severe degeneration of an intervertebral joint he still prefers to use the iliac H-graft: the newer methods of inter-body fusion through the posterior route, and of fusion between the transverse processes, are mentioned but no large experience is claimed.

As always with a Livingstone publication this volume is beautifully produced, but in this instance the use of full colour for the illustrations of operative technique has not given happy results. Good drawings in monochrome might have been clearer and more pleasing, as well as much cheaper to reproduce. In contrast, the coloured line drawings are delightfully clear. The many radiographs are superbly reproduced, but it is a pity that some of them have been placed sideways along the page: it is irritating to have to twist the book round in order to see them. (The same criticism in reviews of the first edition has gone unheeded.) Incidentally, why must the half-tone illustrations be called " Plates " and the line drawings " Figures "? Why not call them all one or the other? The double series of numbers leads to unnecessary confusion.—J. Crawford ADAMS.

BORDERLANDS OF THE NORMAL AND EARLY PATHOLOGIC IN SKELETAL ROENTGENOLOGY. By Prof. Dr Alban KÖHLER. Tenth edition by Dozent Dr E. A. ZIMMER; English translation edited by James T. CASE, M.D., D.M.R.E. (Cambridge), Professor Emeritus of Radiology, Northwestern University Medical School, Chicago; Director, Memorial Cancer Foundation, Santa Barbara, California. 10½ × 7 in. Pp. xiv + 723, with 1,282 figures. Index. 1956. New York and London: Grune & Stratton, Inc. Price £8, 12s.

Every orthopaedic surgeon is brought up to read radiographs himself. Every wise orthopaedic surgeon checks his opinions with those of others, especially radiologists; in this matter there is no room for *amour-propre*. He must draw primarily on his own experience, but there are many difficult cases in which his own experience and that of his colleagues cannot suffice, and he should look to the greater store that has been amassed in the literature.

Few problems are more difficult than a distinction between the " normal " and the pathological, and Alban Köhler found a remarkable field to harvest when his work first appeared in 1910. In its fifth edition it was first translated into English in 1928 as *Röntgenology: The Borderlands of the Normal and Early Pathological in the Skiagram*. The reviewer can speak with enthusiasm of the value of that work, the skeletal part of which occupied 291 pages with 187 figures. The latest translation—of the tenth edition—virtually confines itself to the skeleton: *Borderlands of the Normal and Early Pathologic in Skeletal Roentgenology*. Yet it extends to 707 text pages, with 1,282 figures. This is partly a measure of the advance in our art.

Inevitably the work has become increasingly a pointer to the literature—a sort of library companion —and less directly informative. This being accepted, it is probably well that Dr James T. Case, the present translator, has made good the omission of important articles in English from the bibliography. With the passing years " Köhler " has become less readable but even more omniscient.—H. Jackson BURROWS.

GRAY'S ANATOMY, Thirty-second (Centenary) edition. Edited by T. B. JOHNSTON, *C.B.E.*, M.D., Professor Emeritus of Anatomy, University of London; D. V. DAVIES, M.A., M.B., B.S., Professor of Anatomy, St Thomas's Hospital Medical School, University of London; and F. DAVIES, M.D., D.Sc., F.R.C.S., Professor of Anatomy, University of Sheffield. 10 × 6½ in. Pp. xx + 1,604, with 1,329 figures, 657 in colour. Index. 1958. London: Longmans, Green & Company Ltd. Price £6, 6s.

This unique text-book has now been in existence for one hundred years, and few scientific works in any field can have approached this remarkable achievement. More than five hundred thousand copies of the British editions have been sold since it first appeared in 1858, and a further five hundred thousand have been sold on the other side of the Atlantic. The new edition, with its improved paper and reproduction of illustrations is a worthy successor to the original.

It is interesting to speculate on why this work should have survived. In the first place, when Henry Gray published the first edition one hundred years ago, he was undoubtedly filling a wide demand for a comprehensive text-book in simple English that the student could understand. Perusal of a copy of the first edition shows how well he met that demand. It is borne out by the fact that a

fourth edition was needed only seven years after the first appeared. Secondly, the layout of Gray's original manuscript was such that it lent itself to modification as science advanced without losing the basic character. Thirdly, no scientific work will survive unless every edition is readable, accurate and up to date. Here surely is the main reason why this text-book remains perhaps the most widely used medical reference book in the world today. Herein, also, lies the challenge to the present Editorial Board—every edition of a work such as this must itself create the demand for a further edition.

The text, of course, has been entirely rewritten in the course of years, though wherever possible the general layout has been carefully preserved. In some instances, such as the preamble to the description of the vertebrae, whole sentences are very similarly worded (p. 5 in the first edition, compared with p. 228 in the thirty-second). Twenty-one of the original illustrations remain in the Centenary Edition—four (Figs. 597, 648, 649 and 1,024) have not been altered in any way; the other seventeen have had colour added at various times—a remarkable testimony to the first artist, Gray's colleague, Dr C. V. Carter. Many others remain based upon the originals, having been gradually substituted as the early blocks wore out; without exception they are excellent. The original design of cover was retained almost unaltered until well into the present century, and was very handsome. The present plainer cover is not so good, chiefly because it tends to look much more dilapidated when well worn (and copies of *Gray's Anatomy* get very well worn).

The main changes in the new edition are the inclusion of knowledge gained by electron-microscopy in the sections on histology and embryology, and the addition of more references to recent work. Mention might have been made of Sharrard's important work on the distribution in the spinal cord of the motor cell columns supplying individual muscles (Journal of Bone and Joint Surgery, 1955, **37–B,** 540–557). It is a pity that the section headings are becoming less anglicised: " Angiology " in the new edition replaces " Blood Vascular System " in the previous one. Surely the English is simpler in most instances: why not " Articulations " instead of " Syndesmology," " Muscles and Fascia " instead of " Myology," " Visceral System " instead of " Splanchnology "? Henry Gray labelled these sections in simple English, and it might have been better to have reverted to his own headings where possible in this Centenary Edition, rather than to drift farther away from them. Lastly, has not the time arrived for anatomy text-books to discard the idea of muscles' having an " origin " and an " insertion "? This fixes in the student's mind the idea that when a muscle is acting normally the origin is the fixed point to which the insertion is approximated, whereas, in fact, it only applies to a limb held in space. In many instances the reverse takes place when a muscle is acting naturally. This is especially true in the lower limb. Proximal and distal " attachments " would be better.

It is always easy to criticise a work of this nature, and the foregoing remarks in no way imply that the volume under review does not retain the supremacy in its own field.—J. N. ASTON.

AN INTRODUCTION TO SURGERY. Edited by David H. PATEY, M.S., F.R.C.S., Surgeon, the Middlesex Hospital; Director of Surgical Studies, the Middlesex Hospital Medical School; Examiner in Surgery, Universities of London and Oxford; with fifteen other contributors. $7\frac{1}{2} \times 5$ in. Pp. xi+228, with 54 figures. Index. 1958. London: Lloyd-Luke (Medical Books) Ltd. Price 17s. 6d., Students' edition 9s. 6d.

Although there appear to be too many books published on surgical matters, nevertheless there is a definite need for a book of this nature which the student will find a great help in surmounting a difficult climb in his career when he has just completed his pre-clinical studies and now meets his patients for the first time.

The book is well written. It is rather invidious to select any particular section, but I think that special mention should be made of the excellent chapter dealing with metabolic problems. The text is conveniently divided into general principles, clinical and further investigations, and then a few simple commonplace procedures with which the student should be familiar. The diagrams are simple, clear and informative. The glossary and the appendix of normal values of the various body constituents should prove most useful. I believe that the value of this book to the student could be improved by a fuller explanation of surgical facts, for example the differentiation of the types of deafness by the tuning fork test. There is a surprising statement that the long extensor tendon of the thumb is frayed by the rough groove on the back of the radius in a Colles fracture. Nobody who has seen the condition at operation could accept this.

As an introductory work, this book will be of only temporary use to the student; so the publishers should be congratulated on producing an alternative and cheaper paper-back students' edition. This book can be thoroughly recommended to those embarking on the clinical part of their course.—David TREVOR.

THE CHEMICAL DYNAMICS OF BONE MINERAL. By William F. NEUMAN and Margaret W. NEUMAN. 9¼×5½ in. Pp. xi+209, with 51 figures and 24 tables. Index. 1958. Chicago: The University of Chicago Press. London: Cambridge University Press. Price 37s. 6d.

One's grasp of any scientific problem usually depends directly upon how well one knows the literature. This unfortunately has not been my experience in the field of bone biochemistry. The more I read, the more I became involved in a mass of conflicting and unrelated details, and I am sure that others must have felt themselves in the same situation. This short, well produced monograph by William and Margaret Neuman will help to rescue many of us from our difficulties. It is the most lucid and coherent account of the chemistry and biochemistry of bone that I have ever read. It is also a highly courageous and original contribution—much more than a review and rehash of existing information and hypotheses.

Studies *in vitro* using synthetic hydroxyapatite or bone mineral have allowed an analysis of the exchange of ions between the crystals and surrounding fluid media. The amounts of calcium and phosphate in a fluid similar in composition to extracellular fluid are such that it is supersaturated when in the presence of bone mineral. In the absence of the solid phase, however, such a solution is stable and apatite crystals can be formed only with the help of a seeding mechanism. In the presence of the solid phase, the degree of supersaturation of the fluid can be greatly reduced by various specific ions (notably citrate), so that a close approach to chemical equilibrium is allowed. *In vivo* the skeleton is in biochemical equilibrium with extracellular fluid. There is good evidence that this equilibrium is achieved and regulated by a mechanism depending on the local production of a specific ion, citrate, by bone cells—a mechanism that is sensitive both to parathormone and to vitamin D.

Such in brief is the authors' thesis, and it is very convincingly argued. The chemical foundation has been well laid, but the authors themselves admit ruefully that " in the final phases of construction there was a shortage of good building material—established experimental results." Much more biochemical work is required, but it is clear in what direction the evidence should be sought. The trick in research lies in asking the right questions, and this book should help many workers to formulate these more clearly.—P. G. WALKER.

QUANTITATIVE ROENTGENOLOGIC STUDIES ON CHANGES IN MINERAL CONTENT OF BONE *IN VIVO*. By Karl-Åke OMNELL. 9¾×7 in. Pp. 86, with 12 figures, 16 diagrams and 11 tables. 1957. Stockholm: Acta Radiologica, Supplementum 148. Price 35s.

The usual method of assessing changes in bone calcification *in vivo* is by subjective observation of successive radiographs, and the idea of making this method objective and quantitative is naturally attractive. Unfortunately, the hopes raised by the title of this thesis are not entirely fulfilled, although some meticulously careful experimentation is described.

The first half of the thesis is devoted to an elementary account of the attenuation of x-rays by matter with particular reference to soft tissues and bone, which can be represented physically by water and hydroxyapatite respectively. Simple formulae are derived whereby, given appropriate physical conditions, the amount of bone salt traversed by an x-ray beam can be determined in terms of the equivalent amount of aluminium, which is used as a standard absorbing material. At this stage the author might be criticised for the implied assumption that an ordinary heterogeneous x-ray beam can be represented by a unique mass absorption coefficient, an assumption which, to say the least, is naïve. At the end of some forty pages the somewhat obvious conclusion is reached that the elegant methods of bone salt assay outlined in the theory are quite impracticable in normal radiographic practice. There is, indeed, throughout the report, an irritating tendency to stress the obvious and to over-elaborate descriptive detail.

For the remainder of the thesis the sights are lowered considerably. Although absolute assay of bone salt *in vivo* is impracticable, it is shown that changes in bone density in one particular region can be followed semi-quantitatively by a careful photometric study of serial radiographs taken under exactly controlled geometrical conditions. This is demonstrated by a limited series of experiments on dogs in which either decalcification of the interalveolar bone septum is induced by amalgam filling of neighbouring teeth or recalcification of the septum is observed after injury by burring. The experiments are described in very great detail and all possible sources of error have been studied. Results, shown in a series of curves, indicate that, given sufficient attention to the physical problems involved, an objective assessment of bone density changes is possible. It would be wrong, however, to imagine that this technique has reached a stage where it could be applied to routine radiological and surgical practice.—J. E. ROBERTS.

BONE AND RADIOSTRONTIUM. By Arne ENGSTRÖM, Rolf BJÖRNERSTEDT, Carl-Johan CLEMEDSON and Arne NELSON. Department of Medical Physics, Karolinska Institutet and the Research Institute of National Defence, Stockholm. $9\frac{1}{4} \times 6$ in. Pp. 139, with 59 figures and numerous tables. Index. 1958. Uppsala and Stockholm: Almqvist & Wiksell. New York: John Wiley & Sons, Inc. London: Chapman & Hall. Price 70s.

The appearance of a monograph from the Medical Physics Department of Karolinska Institutet on Bone and Radiostrontium raised great expectations among those interested in radiation hazards from bone-seeking isotopes, because this department has made many valuable contributions to the development of physical methods in the study of bone physiology. As the book is primarily a report of joint research by this body and the Research Institute of National Defence in Stockholm, most of the references are from publications issued from these institutes. Emphasis is therefore placed inevitably on knowledge of bone physiology and structure gained from methods of biophysical investigation such as x-ray microscopy, autoradiography and microinterferometry; and less is said of important advances using biochemical and chemical techniques.

The first chapter has a brief but clear review of certain aspects of recent knowledge on the metabolism of strontium, followed by two chapters on the distribution of mineral salts in the skeleton and the molecular structure of the inorganic phase in bone. The fourth chapter contains an account of the author's original experiments on twenty-five rats. On the basis of the biological data obtained, certain calculations of the dose-rates from the radiostrontium retained in bone are presented in great detail. In the final chapter the authors use the data they have already presented to deduce values for the permissible body burden of radioactive strontium in human beings. From their calculations they suggest on the last page that the greatest permissible level for ^{90}Sr should be reduced from the present figure of $1{\cdot}0\mu c$—recommended by the International Commission on Radiological Production and generally accepted as a working figure—to a figure as low as $0{\cdot}1\mu c$. This is a dramatic reduction in level and, coming from a department of such high standing, is bound to carry considerable weight. It is, however, extremely difficult to follow the argument by which the authors arrive at this figure. It is estimated that certain microscopic areas of bone may receive a dose-rate of 300–500 m rem/day with a body burden of $1\mu c$ ^{90}Sr in a skeleton of 7,000 grammes. This is a factor of 50 to 80 times the dose-rate received, assuming a homogeneous distribution of ^{90}Sr; but nowhere is it made clear how this figure of 300–500 m rem/day was derived from a dose-rate of 5·8 m rem/day to each gramme of bone, assuming an even distribution. The authors state that geometrical and concentration factors must be taken into account; but, even allowing for a concentration factor as high as 10, as they do, and a geometrical factor of 2–3, it is still difficult to follow their calculations. If a universally accepted greatest permissible level is challenged the argument should be made crystal clear.

The monograph is well illustrated with many photographs of apparatus, autoradiographs and charts and diagrams illustrating the points made in discussion. There is a good author and subject index. The book is of great interest to specialists in the field of radiation hazards, but it cannot be recommended to a more general scientific public as a complete survey of present knowledge of the relationship of strontium to bone physiology.—Janet VAUGHAN.

SYMPOSIUM OF TUBERCULOSIS. Edited by F. R. G. HEAF, M.A., M.D., F.R.C.P., David Davies Professor of Tuberculosis, Welsh National School of Medicine, Cardiff; with thirteen other contributors. 10+8 in. Pp. xvi+755, with 78 figures. Index. 1957. London: Cassell and Company Limited. Price £5, 5s.

This symposium is the most comprehensive study of tuberculosis in the English language since Rich published *The Pathogenesis of Tuberculosis* in 1946. Fourteen contributors have written on various aspects and the overall impression is that this is a lucid and authoritative reference book.

Heaf in his general survey and Stephen Hall in a chapter on the prevalence of tuberculosis provide a contemporary picture of the incidence of this disease in relation to heredity, race, climate, diet and occupation, and Geddes covers past and present measures of control. While vaccination is dealt with fully, there does not appear to be a sufficiently critical discussion of the values of vaccination in different ecological situations.

A serious defect in this symposium, especially when contrasted with Rich's book, is the want of a full discussion of pathogenesis and pathology. Cruikshank provides a chapter on infection and immunity, and this is adequate as a summary of the bacteriology, the modes of infection and the tissue reaction when the body first encounters the bacillus. The factors within the host which allow infection to become disease are scarcely mentioned. It is clear from the data provided that most

people who become infected with the tubercle bacillus do not develop tuberculosis. Dubos has pointed out that " infection is in many cases the normal state; it is only disease which is abnormal." Infection for most people is terminated when the bacilli are locked up in a caseous focus, and tuberculosis begins when this natural hard caseous focus softens. The role of psychological and endocrine disturbances, trauma and superimposed infection which bear on this aspect of pathogenesis is not considered.

Respiratory tuberculosis is dealt with very fully in two chapters, the second covering various forms of surgical treatment. Not all practitioners would agree with the dogmatic statements about the value of strict bed-rest, and the complications of immobilisation osteoporosis are not mentioned. Wilkinson's chapter on non-respiratory tuberculosis is a most admirable monograph in its own right.

It is encouraging to find so much space given to the consideration of tuberculosis in industry and rehabilitation, and orthopaedic surgeons may well find the chapter on rehabilitation the most valuable in the book.——C. H. LACK.

DIE HEUTIGE BEHANDLUNG DER SKELETT-TUBERKULOSE DES KINDES UND DES JUGENDLICHEN. By Georg GLOGOWSKI, Wissenschaftlicher Oberassistent an der Orthopädischen Klinik München. Foreword, Prof. Dr Max LANGE. $9\frac{1}{2} \times 6\frac{1}{2}$ in. Pp. 61, with 54 figures and 21 tables. 1957. Stuttgart: Georg Thieme Verlag. Price DM 12.

This treatise on the up-to-date treatment of skeletal tuberculosis in children and juveniles is based on the experience gained in the treatment of such cases at the Munich Orthopaedic Clinic during the last ten years, after the introduction of chemotherapy and antibiotics. Great satisfaction is expressed over the lowered mortality, the shortened duration of treatment necessary and the larger proportion of movable joints obtained compared to the former days. The value of intra-articular injection of antibiotics is mentioned, as is the use of early extensive biopsy under an adequate umbrella. The latency of definite radiographic diagnosis is stressed; it is stated to be one to five months in the spine. The evacuation of abscesses is advised; and, if they are in bone, their replacement by cancellous bone, after curetting, is practised. Many radiographs of excellent quality, depicting lesions before and after treatment, are well reproduced. The findings, methods and results are on the whole very like those of other centres.—Robert I. STIRLING.

DER HEUTIGE STAND DER LEHRE VOM SUDECK-SYNDROM. By Carl BLUMENSAAT, Chefarzt des Knappschafts-Krankenhauses Bottrop, Westf. $9\frac{1}{2} \times 6\frac{1}{2}$ in. Pp. viii + 225, with 25 figures. 1956. Berlin, Göttingen, Heidelberg: Springer-Verlag. Price DM 29.60.

This monograph on Sudeck's disease deals mainly with the German publications which have appeared since the original paper by Sudeck in 1900. Anyone who is interested in this peculiar syndrome will be very thankful to Blumensaat for his enormous labour in reviewing more than a thousand papers and so giving us a good survey of the present-day conception of etiology and pathogenesis of Sudeck's disease. But the reader must not expect this book to give him an answer to the question what Sudeck's disease really is. Despite the flood of publications there is no agreement on the definition of the syndrome and the different theories on pathogenesis are too often based upon mere suppositions and not facts. It is widely accepted that the frequency of Sudeck's syndrome after injuries is much higher on the European continent than in England or in the U.S.A., the reason for this difference being obscure. But it is amazing to hear that after World War II the frequency of Sudeck's disease after injuries has doubled in Germany and follows about 22 per cent of fractures in general. Of fractures of the leg not less than half the cases are said to be complicated by the syndrome. It is difficult to explain these alarming figures. Either something is wrong with the fracture treatment of the authors who published these figures or—what seems to be more reasonable—diagnosis of Sudeck's disease is made too readily and is confused with simple post-traumatic osteoporosis.

Analysing the pathogenesis of Sudeck's disease, most authors stress humoral and reflex vasomotor factors and an abnormal mode of reaction of the autonomic nervous system. Blumensaat and most German authors think that disuse does not play any role in pathogenesis of the osteoporosis observed in Sudeck's atrophy, a conception difficult to support by clinical and experimental facts.

The monograph, aiming at no more than a review of the literature, fulfils this purpose extremely well and demonstrates how little we know about Sudeck's disease, and how great a playground for undisciplined thinking this peculiar syndrome is. It is to be hoped that in a second edition of his monograph Blumensaat is not condemned to review another thousand papers.—Max GEISER.

STUDIES IN SPONTANEOUS ATLAS DISLOCATION. By Sven WERNE. 9×6¼ in. Pp. 150, with 48 figures. 1957. Copenhagen: Ejnar Munksgaard. Acta Orthopaedica Scandinavica, Supplementum No. XXIII. Price 45s.

SO-CALLED SPONTANEOUS CERVICAL DISLOCATIONS. By Tormod HAUGE. 9¾×6¾ in. Pp. 28, with 11 figures. 1958. Stockholm: Acta Chirurgica Scandinavica, Supplementum No. 232. Price Sw. Kr. 8.

These two essays have a good deal in common though the subject is treated in different ways. Sven Werne writing from the Orthopaedic and Anatomy Departments of the University of Lund gives a new account of the anatomy of the joints between the occipital condyles, atlas and axis and of the ligaments that unite them. Here are carefully made measurements of the range of movements in each joint. These are the best to date. Some points difficult of direct observation have been studied by the construction of models. More important still is Werne's description of the ligaments and their behaviour in extremes of normal movement. These, together with the intrinsic factors provided by the dimensions and planes of the articular surfaces, are of course the limiting factors in the types and directions of movement. There are numerous line drawings illustrating this part as well as of the plan and behaviour, when stretched, of the alar ligaments in particular. Werne has taken great pains to observe these by dissection and to record his findings diagrammatically. One of his most interesting conclusions is that the alar ligament becomes taut on rotation, so that in extreme rotation both these ligaments are tight. The other movement that stretches them is extreme latero-flexion of the head. These conclusions by Werne strike your reviewer as having a considerable bearing on the mechanism of odontoid fracture, one that he has long regarded as a traction fracture. Passing on now to the clinical part of Werne's paper, we find that he presents seven cases of " spontaneous " atlas dislocation which is no more spontaneous than a box of matches! The term non-traumatic is much to be preferred. Werne remarks that a search of the literature had not revealed any description of the mechanics of atlas dislocation. This is presumably because he has not studied the literature of trauma and has missed the contributions of E. M. Corner (e.g., *Annals of Surgery*, 1907, **45**, 9) or even of your reviewer. His own work is certainly more complete. In Werne's cases the radiological evidence of a stretched transverse ligament is convincing in five of the seven cases; he claims no more. Recent naso-pharyngeal infection and rheumatic polyarthritis were the usual causes of ligamentous softening. There are excellent clinical photographs of his patients, mostly girls.

At this point the study by Tormod Hauge from the Neuro-Surgical Department of Rikshospitalet at Oslo takes the pathology of this condition much further. As would be expected from their source, in the five cases in this group severe pain or spinal cord involvement were leading features. Two deaths after operation (one from air embolism, the other in a dilapidated man aged sixty-four) provided material for histology. Chronic destructive inflammation was found in one, floridly characteristic of rheumatoid arthritis with giant cells, macrophages and plasma cells; the odontoid process had been converted into a cystic shell by this disease. In the others the inflammation was non-specific. Two of the five cases were not examples of dislocation of the atlas, but of the fourth cervical vertebra on the fifth and of the fifth on the sixth. Since all of the patients were operated upon by laminectomy and spinal fusion, biopsy tissue was available. It showed the same changes in these lower lesions as in the atlanto-axial ones. Hauge's cases were of a severer, more advanced type than Werne's and go a long way to advance our knowledge of the pathology of these important bony and ligamentous lesions in the upper part of the spine. This is first-rate work and demonstrates that the bones as well as the soft tissues are affected. To add that this is more evident in the older examples is to state the obvious.—Geoffrey JEFFERSON.

PSEUDARTHROSE CONGÉNITALE DU TIBIA et son traitement. By M. GUILLEMINET and R. RICARD. 10×6½ in. Pp. 98, with 78 figures and table. 1958. Paris: Masson et Cie, Editeurs. Price 1,800 fr.

No one who reads this book could complain that the subject is not dealt with fairly comprehensively. The condition is defined; its etiology is discussed; its pathology is analysed; its clinical features and pathogenesis are set out; its treatment is detailed—both under the heading of the methods and under the heading of indications; the prognosis is envisaged; the results are tabulated; conclusions are drawn up; and finally there is an extensive bibliography. I must admit that if anyone were to ask me to write a hundred pages on congenital pseudarthrosis of the tibia, I would shudder, and I would expect potential readers to react similarly. But in fact, with bold type, ample references, generous illustrations and a few blank spaces, the authors have filled the space from cover to cover with success and interest.

The literature is extensively reviewed, and all the methods I have ever heard of, and some I have

fortunately not heard of, are vividly described and illustrated. It is perhaps surprising that Putti, though referred to in the text, is not included in the bibliography. Certainly he employed successfully the operation of replacing the tibia by the fibula, rightly attributed to Hahn and later Huntington, and also described by Scaglietti (1936). It is no good pretending that I like all the metal in bone that is illustrated, nor is the placing of a Küntscher nail across two epiphysial zones attractive. And as for encircling the tibia with four wire bands (p. 57, Fig. 10c) " c'est magnifique, mais ce n'est pas la chirurgie des os." It is surprising after reading this remarkable volume that one should in fact still have any difficulties. Nevertheless I could not find an explanation of the calcaneus deformity which almost inevitably accompanies the established pseudarthrosis.

The authors stress the advisability of operating at an early age—" dans les premières années de la vie," though they do say that older children, even adolescents, are easier to treat and recover more certainly. That is my own experience which now covers of course much more than the nine cases quoted in this volume, and the only real failure in my series was a child on whom I first operated at seven months. I think that some of the methods illustrated in this book have succeeded only because the children were considerably older than those I usually have to deal with. This does not mean that I disagree with the authors when they choose three to four years as the best age, for quite rightly they point out that the secondary effects of persistent non-union are serious and to some extent irreversible.

In dealing with prognosis, the authors stress the potential fallacy of deciding too quickly that a permanent cure has been obtained. I find this quite judicious, but I was disappointed not to find any discussion of the level of " dis-union " as a prognostic factor. I believe that the higher the pseudarthrosis lies in the tibial shaft, the better is the prognosis. The reviewer's clinical views, however, may be a little out of place here, and it would be as well to end by advising everybody interested in, or responsible for, the orthopaedic treatment of children to have a copy of this book and to read it.—Bryan McFarland.

REFERENCE

Scaglietti, O. (1936): Il perone in posto della tibia. Estratto del Bollettino e Memorie della Società Emiliano-Romagnola di Chirurgia, Bologna. **11,** Fasc. 11. Bologna: L. Cappelli, Editore.

VITALLIUM MOULD ARTHROPLASTY FOR OSTEOARTHRITIS OF THE HIP JOINT. A study of the Ability of the Method to Create a New Joint in an Anatomical-Physiological and in a Clinical Sense. By Arnt Jakobsen, M.D., Staff-Surgeon Oslo City Hospitals, Surgical Department III Ullevaal; Lecturer in Surgery, University of Oslo. $10\frac{1}{4} \times 7\frac{3}{4}$ in. Pp. 238, with 27 plates and 52 tables. 1958 New York and London: The Macmillan Company, New York. Price 63s.

This monograph is based on the follow-up of 301 operations of cup arthroplasty. The book begins with a detailed historical survey of the treatment of arthritis of the hip, and this is followed by an account of the symptoms of the disease. Both chapters are rather tedious and could be omitted without interfering with the main substance of the work. There is a very good description of the operation, which is well illustrated by drawings; and it is apparent, from the close adherence to the original technique, that the author has come under the influence of the late Dr Smith-Petersen himself. Bone grafting, to conserve the head of the femur, and derotation osteotomy are modifications that Dr Jakobsen has found rewarding. The necessity for prolonged after-care is stressed, and at least one year of continuous physiotherapy is advised, with courses of exercises every six months over the next two years.

The 250 patients have been under observation for three to seven years. Only one immediate post-operative death is reported; but, in all, ten patients died in the first three years. The remaining 240 patients have been examined and the cases put into four categories: excellent, good, fair and poor. These results have been obtained by giving points for pain, mobility and stability. The cases are analysed under nine different etiological groups, and finally assessed as a whole. The final results compare very favourably with other methods of arthroplasty. Nearly 70 per cent of patients were completely free from pain, and 58·5 per cent had excellent mobility. A high incidence of minor instability makes the author's evaluation of excellent results as only 26 per cent; but, in contrast to this, 57·8 per cent of patients were very well satisfied and 24·6 per cent satisfied. Thus over 80 per cent of patients were convinced that the operation and prolonged after-treatment were really worth while.

Dr Jakobsen concludes with these sentences: " Vitallium mould arthroplasty is not an ideal method as the result in the individual case is unpredictable. However, it is considered the best method for surgical treatment of osteoarthritis of the hip joint used today in hospitals staffed and equipped to master the technique." This attitude towards the operation is surely one of the main reasons for his very successful results, and it should be a warning to many of us not to embark upon the procedure unless the proper facilities are available. I heartily recommend this book to anyone who is interested in the problem of hip arthroplasty.—J. N. Wilson.

HOFTEALLOPLASTIK FRACTURA COLLI FEMORIS FØLGETILSTANDE HEREFTER. Alloplasty of the Hip as Treatment in Suitable Cases of Fracture of the Neck of the Femur and in Sequels of Such Fracture. By R. MOVIN. $9\frac{3}{4} \times 6\frac{3}{4}$ in. Pp. 275, with 90 figures. Summary and Conclusions in English. 1957. Copenhagen: Ejnar Munksgaard. Price Dan. Kr. 25.

This careful monograph is well produced and ends with a summary in English of each chapter extending to no less than seventeen pages. It gives the results up to date of 286 replacement operations, of which 196 were for fractures of the neck of the femur and its complications. At first the Judet prosthesis was used, but later one or other of the author's own three models, especially the

FIG. 13

Type B design (fifty-nine operations). This is described as a calcar-supported acrylic-steel prosthesis (see Fig.) which is a satisfactory compromise between the small Judet and the large Moore or Thompson patterns. Dr Movin has little to say about this method of treatment for osteoarthritis. This monograph is yet another example of the high standard of work of the Scandinavian school of orthopaedic surgery and should be studied by all those interested in this particular field.—K. I. NISSEN.

SKIN ARTHROPLASTY OF THE HIP JOINT AND CORRESPONDING ALLOPLASTIC METHODS IN THE LIGHT OF A CLINICAL STUDY. By Erkki KALLIO. $9\frac{1}{4} \times 6\frac{1}{4}$ in. Pp. 99, with 38 figures and 18 tables. 1958. Acta Orthopaedica Scandinavica, Supplementum No. XXX. Copenhagen: Ejnar Munksgaard. Price Dan. Kr. 25.

This monograph is based on the study of 171 arthroplasties for hip diseases. Among these are fifty-three skin arthroplasties. Very little is known about the operation in this country so that it is interesting to find that the results compare favourably with those obtained by using the more conventional methods of the Vitallium mould or the prosthetic replacement. The period of observation however is relatively short (only two years) and obviously it is not long enough to allow any lasting conclusions. Also the prosthetic replacements used in the comparison are all of the Judet type.

The technique of the operation is described in detail. The skin is used in the same way as fascia was employed in older methods. In the cases described the skin was taken from the abdomen and the defect closed by simple suture. The subcutaneous fat was left on the graft and the whole thing applied over the head of the femur, skin surface to bone. It was held in position by a metal purse-string suture; the latter having the added function of acting as a radio-opaque marker for the base

of the "skin cup." The after-care was the same as for a cup arthroplasty. This in general was very much shorter than after the equivalent operation in this country, most of the patients being discharged from the hospital to exercise at home after six weeks. With this régime almost 70 per cent of patients were stated to be very satisfied or satisfied, and 30 per cent uncertain or dissatisfied. Prosthetic replacement gave the best results: there was very little to choose between those of skin arthroplasty and the Vitallium mould operation.

For those who are concerned in the treatment of the stiff hip this book provides yet another sidelight on the problem. It is certainly interesting to know that skin arthroplasty is a possibility; but the fact that an operation can be performed is no criterion of its practical use, and there will have to be a much longer period of observation before the operation can be considered anything more than an experimental procedure.—J. N. WILSON.

DIE PROGNOSE DER WIRBELSÄULENLEIDEN. Prognosis in Vertebral Disease—A review of its occupational significance. By Prof. Dr J. E. W. BROCHER, Genf. $9\frac{1}{2} \times 6\frac{3}{4}$ in. Pp. viii+67, with 45 figures. 1957. Stuttgart: Georg Thieme Verlag. Price DM 12.80.

Social insurance has enormously increased the importance of disease and accidents affecting employability. The efficiency of the vertebral column in relation to the work chosen is a fundamental item of knowledge in placing a worker correctly and avoiding adjustment later. Increasing knowledge of vertebral pathology is in danger of outrunning its practical application. Nowhere is this more obvious than in the study of spondylolisthesis. It is apparent that this condition is much more common than has formerly been suspected, and that it often only manifests itself in the second and third decades, by which time a man has chosen his work and been trained in it. Discovery frequently forces a change of employment which may necessitate expensive retraining and social readjustment, often a difficult and trying experience.

The size of the problem has been emphasised by recent figures reviewing the spinal condition in uncomplaining heavy workers. In 4,654, Runges found pathological changes in 25 per cent. Allen and Lindem in 3,000 cases found 13 per cent with degenerative changes (osteoarthritis) and 2·96 per cent with spondylolisthesis. Marsh and Rombold in 572 candidates for work found only 63·8 per cent with normal spines: sacralisation of the last lumbar vertebra was found in 7·7 per cent, narrowing of the lumbo-sacral disc in 7·7 per cent and spondylolisthesis in 4·4 per cent.

This volume reviews the effects of spinal disease on employability, and to a lesser extent its influence on accident liability and compensation, and ends with a plea for routine examination before training for employment. In view of the fact that in mass radiography of the chest only some 4 per cent of significant abnormalities are found, it would seem reasonable that the same method should be applied to the spine. While figures cannot adequately be compared from a selected group of workers, the probabilities are that a far higher percentage of abnormalities would be discovered in routine mass radiography of the lumbar spine, than in mass radiography of the chest.

This is primarily a volume for the Industrial Medical Officer and for those interested in social insurance and preventive medicine. It suggests more than it proves, but it points to the goal towards which the combined fields of orthopaedics, radiology and social medicine are slowly pressing, namely a complete health assessment as the basis of employment; not to each according to his needs but to each according to his health.—J. G. BONNIN.

ANAESTHESIA. British Medical Bulletin, Volume 14, Number 1, January 1958, with twenty-two contributors. $11\frac{1}{4} \times 8\frac{3}{4}$ in. Pp. xv×72, with 29 figures and numerous tables. 1958. London: Medical Department of the British Council. Paper cover. Price 20s.

It is twelve years since the publication of the last British Medical Bulletin on anaesthesia. Comparison between the contents of the two emphasises the changes that have taken place. Increased complexity of new anaesthetic methods has called for greater collaboration between anaesthetist, pharmacologist, physicist and biochemist, and this trend is reflected in the articles presented.

The bulletin consists of seventeen articles contributed by different writers. About one-third deal with the conduct of anaesthesia. Five are concerned with biochemistry in relation to anaesthesia, and three with physics as applied to anaesthesia. Muscle relaxation is dealt with in two articles—one on the myoneural action of anaesthetic drugs, and the other on the present theory of the action of muscle relaxants. The present position of hypothermia is described, and in the same paper the treatment of sudden cardiac arrest is clearly and concisely outlined. The treatment of respiratory

inadequacy due to poliomyelitis, tetanus and narcotic poisoning is reviewed. Hypotensive anaesthesia is discussed in two papers—one presenting the advantages, the next the disadvantages.

Finally, in a short article on the investigations into death associated with anaesthesia, one thousand collected cases provide interesting and valuable data. It is notable that, of the deaths, 11 per cent were due to vomiting or regurgitation with inhalation of vomit. The contributions are anonymous and it is unfortunate that there is no indication of the status and experience of the anaesthetist.

This bulletin can be read with profit by anaesthetists, and two articles that would be of interest to the orthopaedic surgeon are "The Treatment of Respiratory Inadequacy" and "The Muscle Relaxants: Recent Developments."—G. K. T. ROCHE.

MODERN TRENDS IN ANAESTHESIA. Edited by Frankis T. EVANS, M.B., F.F.A.R.C.S., D.A., and T. Cecil GRAY, M.D., F.F.A.R.C.S., with 22 contributors. 10×7 in. Pp. ix+318, with 27 figures. Index. 1958. London: Butterworth and Co. (Publishers) Ltd. Price 67s. 6d.

It is refreshing to read a new book on anaesthesia which approaches the subject from a fresh angle. This is not so much a factual account of the latest work in various fields as a series of essays, dealing with the broad outline of theory and practice. These are written in a somewhat philosophical vein and indicate where possible the general lines on which future progress may be expected. Each chapter is followed by a comprehensive list of references.

Anaesthesia has made such strides in recent years that trainees tend to become absorbed in trying to assimilate vast numbers of seemingly unrelated facts and finish up in a muddle—they cannot see the wood for the trees. To such readers this book should be especially valuable as it should help to restore their perspective. It should be emphasised that this is not a text-book, nor is it light diet for beginners. A considerable amount of theoretical and practical knowledge is essential before it can be read with profit.

The primary task of the editors was the selection of an able team of contributors, and there is no doubt that this has been successfully accomplished. The writer of each chapter is an acknowledged expert on his subject and the choice has not been limited to British workers. Such renowned authorities as Dr J. J. Bonica of Washington, Dr A. B. Dobkin of Saskatoon, Dr E. M. Papper of New York and Dr Eric Nilsson of Lund have been included.

The orthopaedic surgeon will probably be most interested in the chapters on "The anaesthetist in the paediatric unit" by Dr Jackson Rees and "The pituitary-adrenal system and anaesthesia" by Dr E. F. Scowen. He will also note the account of the use of hypnosis in orthopaedic manipulations by Dr A. A. Mason. It seems rather a pity that the many problems connected with pulmonary and cardiac surgery as a whole are not discussed although Dr Cecil Gray deals excellently with hypothermia and Dr D. Melrose with cardio-respiratory pumps.

This book is emphatically one to read, mark, learn and inwardly digest.—C. Langton HEWER.

ATLAS OF ARTHROSCOPY. By Masaki WATANABE, Sakae TAKEDA and Hiroshi IKEUCHI, the Department of Orthopaedic Surgery, Tokyo Teishin (Postal Services Ministry) Hospital, Tokyo. $10\frac{1}{4}\times7\frac{3}{4}$ in. Pp. 53, with 68 figures, the majority in colour. 1957. Tokyo: Igakushoin. Price $10.

An arthroscope was made in Japan as long ago as 1920 and modifications have been in more or less constant use in that country ever since. A considerable experience of arthroscopic appearances has therefore been accumulated and a fraction of it is presented here. The book takes the form of an atlas containing sixty-eight illustrations, all of the knee, beautifully reproduced from paintings. A brief history of each patient is given, but the descriptions and explanations of the illustrations are not sufficiently detailed to enable an inexperienced reader to appreciate them fully.

Endoscopy inevitably causes some damage to the synovial membrane and joint capsule; but, since no information is given about the subsequent reaction, it is impossible to judge the circumstances in which the obvious disadvantages, as compared with arthrotomy, are likely to be outweighed by the advantages. But whether or no endoscopy is desirable as a routine clinical procedure, it is certainly a wonderful tool for research because it enables the synovial membrane to be observed in fairly natural conditions; this should make it possible to solve several outstanding problems, for example the correlation between the pathological and the clinical features of the several forms of synovitis.

The authors state that they intend to present a more comprehensive atlas of endoscopic appearances when it is financially possible, and this is awaited with interest. It is hoped that they will then be able to make use of photographs instead of paintings, and include more descriptive material.—Philip WILES.

AN INTRODUCTION TO ELECTROMYOGRAPHY. By Fritz BUCHTHAL, M.D., Professor of Neurophysiology, University of Copenhagen, Consultant in Clinical Neurophysiology to the University Hospital. 10×7 in. Pp. 43, with 8 figures and a table. Index. 1957. Copenhagen: Gyldendals Presseafdeling. Price Danish Kr. 7.50.

The electromyograph is no longer the perquisite of the research worker and it is now used in the routine investigation of disorders of the locomotor system. This excellent little monograph by Professor Buchthal can be described as " electromyography without tears." In forty-three pages the technique is described in detail and the typical findings in normal and abnormal muscle are clearly illustrated. In addition there is a useful bibliography of the more important literature. For those who are completely ignorant of the technique and for those with a little knowledge, this book will prove most helpful.—Donal BROOKS.

FONCTIONS ET BILAN ARTICULAIRES. By Ch. ROCHER, Ancien Chef de Clinique chirurgicale et orthopédique, Chef de Service de Kinésithérapie, and A. RIGAUD, Professeur agrégé D'anatomie à la Faculté de Médecine de Bordeaux. 9½×6½ in. Pp. xi+271, with 194 figures. 1956. Paris: Masson et Cie, Editeurs. Price 2,350 fr.

This book is concerned with the function and kinesiology of joints. It is divided into two parts. The first part deals with the functional anatomy of joint movement in the normal and pathological state. Methods of measuring and recording the range of movement of each joint are described in great detail. In the second part of the book techniques commonly used in the restoration of joint movement by active and passive movements are discussed.

In summary, a great deal of common knowledge on this subject is reiterated in a long-winded fashion.—Donal BROOKS.

SUSPENSION THERAPY IN REHABILITATION. By Margaret HOLLIS, M.C.S.P., Principal, School of Physiotherapy, Bradford Royal Infirmary; and Margaret H. S. ROPER, M.C.S.P., Lecturer in Physiotherapy, University of Cape Town; with a foreword by Sir Arthur PORRITT, *K.C.M.G., K.C.V.O., C.B.E.*, M.Ch., F.R.C.S., Sergeant Surgeon to H.M. the Queen, Surgeon to St Mary's Hospital, Paddington, and the Royal Masonic Hospital, London. 8¾×5½ in. Pp. xii+220, with 112 figures, 22 plates and frontispiece. Index. 1958. London: Baillière, Tindall and Cox. Price 25s.

Guthrie Smith's " slings and springs " have become an integral part of the modern physiotherapy department. This book contains a complete review of the mechanical principles, techniques and clinical application of Guthrie Smith's methods. The illustrations by line drawing and photographs are excellent and make the subject matter easy to follow. Although designed primarily for students of physiotherapy this book will be of considerable value to those orthopaedic surgeons who retain an interest in the physiotherapy department.—L. W. PLEWES.

THE REHABILITATION OF AMPUTEES. General Principles drawn up by a Sub-Committee of the Brussels Treaty Organisation (now the Western European Union). Ministry of Health. 9¾×6 in. Pp. 20, with 8 plates. 1957. London: Her Majesty's Stationery Office. Price 2s. 6d.

There is little in this pamphlet that is new. It states the general principles in the rehabilitation of amputees as agreed by a Sub-Committee of the Western Union, comprising representatives from Belgium, France, the Netherlands and Great Britain, under the Chairmanship of Dr Langdale Kelham. The illustrations are good and, as with the script, betray the authentic note of Roehampton and the influence of the Chairman.

Among general principles, it is worth reiterating that all who undergo an amputation suffer psychological trauma to a greater or lesser degree, and stressing the need to dispel at the outset the fears and anxieties by outlining the secure prospects open to almost all amputees in these countries. The case is well made for a training centre in walking and in the use of arm prostheses in association with the limb fitting centre. Amputees undoubtedly benefit from example and competition, and need to be emancipated from the protective influences of home and the smaller hospitals; and the association with the limb fitting centre enables adjustments to the limb to be effected expeditiously on the spot. The pamphlet goes into considerable detail over the equipment required and exercises advocated in

such a centre, including a useful series of tests on completion of the course of training; the ability to rise from the fallen position is a valuable inclusion in these. This section, with its illustrations and detail, provides a useful guide to anyone starting such a training centre for amputees and would seem to be the justification for the publication.

In the section dealing with the artificial limb, mention is made of the growing tendency to use the more anatomical fitting for the thigh socket rather than the conventional " plug fitting " socket. No casting vote is given between the merits of the all-wood socket and the leather socket in a metal limb. Appendix 6 touches lightly on the appliances for an artificial arm but is unable in the available space to go into any detail.

Appendix 3 on Technique of amputations merely states what is established practice in this country. On the matter of the best sites for amputation, less than justice is done to the Lisfranc and Syme's amputations which, when properly handled from the outset, yield considerable advantages by retaining more of the limb.

A final paragraph stresses the need for research, not only by the limb makers, but by the national organisation which should make a far greater contribution because of greater resources. No mention is made of the results of fundamental research in other countries.—A. L. EYRE-BROOK.

PHYSIOTHERAPY IN PARAPLEGIA. By Elvira P. G. HOBSON, F.C.S.P., a Superintendent Physiotherapist, King's College Hospital, London. With a Foreword by L. GUTTMANN, *O.B.E.*, M.R.C.P., Director of the National Spinal Injuries Centre, Stoke Mandeville. $8\frac{1}{4} \times 5\frac{1}{2}$ in. Pp. viii+110, with 30 figures. Index. 1956. London: J. & A. Churchill Ltd. Price 12s. 6d.

The successful rehabilitation of the paraplegic patient is the outcome of months of perfect team work. It is true to say that no one member of the team can be singled out for special praise. The physiotherapist however sees more of the patient than anyone else and her help and encouragement are immeasurable. In addition to these qualities she must possess the technical skill and judgment which can only be gained by a complete knowledge of the problems involved.

In six chapters Miss Hobson covers her subject admirably. The text is well illustrated. The book is primarily intended for physiotherapists but will be helpful to doctors and nurses who are faced with the care of these patients.—Donal BROOKS.

SIR GEORGE BUCKSTON BROWNE. By Jessie DOBSON, B.A., M.Sc., Curator of the Hunterian Museum, Royal College of Surgeons of England; and Sir Cecil WAKELEY, *Bt.*, *K.B.E.*, *C.B.*, LL.D., D.Sc., F.R.C.S., F.R.A.C.S., F.A.C.S., Past-President of the Royal College of Surgeons of England; Senior Surgeon, King's College Hospital. With a Foreword by Emeritus Professor Sir Harry PLATT, LL.D., M.D., M.S., F.R.C.S., F.A.C.S. 9×7 in. Pp. viii+143, with 28 figures. Index. 1957. Edinburgh and London: E. & S. Livingstone Ltd. Price 25s.

There are two groups of medical men to whom this book must make a special appeal—the urologists, for Buckston Browne was possessed of preternatural skill in treatment of diseases of the lower urinary tract, and also every fellow and member of the Royal College of Surgeons of England, for he made financial provision for an annual dinner at the College, at least half the guests to be members; the Buxton Browne Research Farm also perpetuates his name.

One of the authors had the privilege of intimately knowing the subject of this biography during the last fifteen years of his life, and many of Sir Buckston's case histories were left to him. Buckston Browne's professional skill and deep humanity brought many interesting nineteenth century personalities within his ken, and in this book accounts of some of these are to be found.

The appreciation by Sir Hugh Lett which forms the last chapter, affords a delightful picture of the environment of London surgery at the close of the last and beginning of the present century: it includes the story of the training of patients about to embark on " catheter life " and refers to two men who lived to be a hundred, although since eighty they had been entirely dependent on the catheter.

Some older readers scarcely require the reminder how keen a walker he was to the end of his days and will remember him as he strode in his nineties round the Outer Circle of Regent's Park. Like Bland-Sutton, he wrote all his letters in his own hand. For thirty years he took no holiday; nevertheless he almost celebrated his ninety-fifth birthday.

The book contains some interesting illustrations and commemorates the life of service of a very remarkable man.—Gordon GORDON-TAYLOR.

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These books are acknowledged with grateful thanks. Selections will be made for review as space permits and in accordance with their interest for our readers.

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Lancet
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Radiology
Revista de Ortopedia y Traumatologia
Revue de Chirurgie Orthopédique
Surgery, Gynecology and Obstetrics
Zeitschrift für Orthopädie und ihre Grenzgebiete

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